Longman Certificate Notes

Biology

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Biology

R.M. Foster B.Sc.

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1 Characteristics of living organisms

Living organisms differ from non-living matter in that they perform the following life processes:

Movement
Reproduction
Respiration
Irritability
Excretion
Nutrition
Growth

All living organisms are made of basic units called cells.
Unicellular organisms consist of *one cell* only: e.g. Amoeba.
Multicellular organisms consist of *more than one cell*: e.g. Man.

Structure of a cell and functions of its parts

Protoplasm is the material from which all cells are made. It is usually 66% water and contains 32 elements, the main ones being – carbon, hydrogen, oxygen, nitrogen, sulphur, phosphorus. It can change from a jelly-like *gel* to a liquid *sol* state. Protoplasm outside the nucleus is called *cytoplasm*.

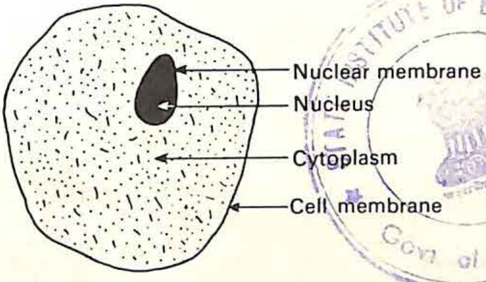

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fig. 1 Basic cell structure

Functions

a Production of secretions: e.g. enzymes, storage materials, new cell materials;

b Provision of a medium in which the chemical processes essential to life can be carried out;

c Transport of oxygen, carbon dioxide, water, nutrients;

d Movement in some cells.

The cell membrane is made of protein and fat.

Functions

a It forms a boundary to keep the cell shape;

b It is semi-permeable, allowing water through by osmosis;

c It is selectively permeable to salts, sugars, and other substances, allowing some to pass but preventing others.

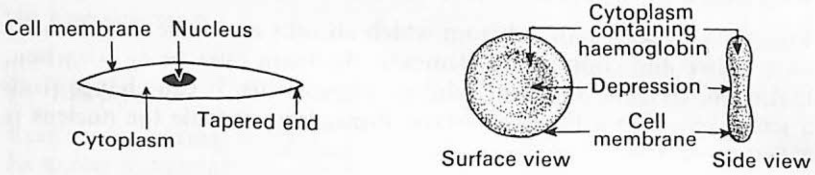
The nucleus is made of specialised protoplasm and is bounded by a nuclear membrane. It is generally invisible in a living cell, but stains readily.

Functions

a It contains *chromosomes* composed of D.N.A. which carries the hereditary characteristics;
b It controls the chemical processes of the cell·
c It initiates and controls cell division.

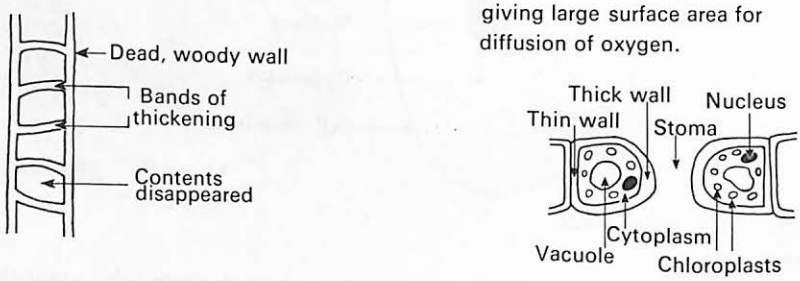
FORM AND FUNCTION

All cells of a multicellular plant or animal are adapted to perform one particular function by their size, shape and chemistry as shown by fig. 2a, 2b, 2c and 2d.



a Mammalian smooth muscle fibre

b Mammalian red blood corpuscle Disc shaped and bi-concave giving large surface area for diffusion of oxygen.



c Xylem vessel of a flowering plant. Narrow tube for capillarity. Dead, woody, strong to withstand pressure of water column moving up plant.

d L.S. guard cells of a stoma in the leaf of a flowering plant.

fig. 2 Specialised cells

Tissues are composed of many cells of the same type packed together, and all performing the same function to carry it out more efficiently: e.g. nervous tissue is composed of nerve cells.

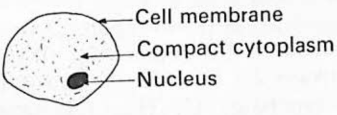
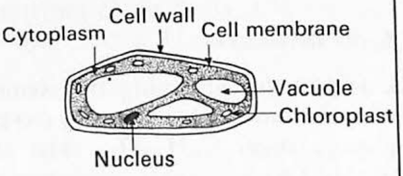
Organs are usually composed of different tissues arranged together, all performing different functions to enable the organ to perform its particular task: e.g. the heart contains the following tissues – muscular, nervous, blood, connective, epithelial.

Similarities and differences between animals and plants

SIMILARITIES

They both perform the seven life processes.

DIFFERENCES

Animals	Plants
Nutrition Animals take in complicated foods and break them down by digestion to simpler forms which can be used by the body.	Plants take in simple substances and build them up by synthesis: e.g. photosynthesis in a green plant: $6CO_2 + 6H_2O \xrightarrow[\text{chlorophyll}]{\text{light energy}} C_6H_{12}O_6 + 6O_2$
Movement Most move their whole body and perform locomotion to find food.	Most can only move their parts. No need to move for food.
Growth Grow all over. Produce a compact body. Growth usually stops at sexual maturity.	Many grow from root and shoot tips only. Produce a branching body. Growth continues throughout life.
Irritability Respond quickly after a brief stimulus.	Respond slowly after the stimulus has been applied for some hours.
Cell structure  fig. 3 Typical animal cell	 Cell wall Cytoplasm Cell membrane Vacuole Chloroplast Nucleus fig. 4 Typical plant cell
No cell wall. Cytoplasm compact. Any vacuoles small and temporary. No chloroplasts.	Cellulose wall giving definite shape. Cytoplasm in threads. Vacuoles large and filled with sap. Chloroplasts containing chlorophyll.

2 Nutrition

Nutrition is the means by which a plant or an animal obtains food materials and changes them into a form which can be used by the body.

Types

Holozoic nutrition Characteristic of *animals*. The *breaking down* of complex compounds by digestion into simpler substances which can be absorbed.

Holophytic nutrition Characteristic of *green plants*. The *building up* of simple compounds into complex ones that can be used.

Parasitic nutrition One organism, the *parasite*, obtains its food by living on or in another living organism, the host: e.g. fleas suck the blood of mammals.

Saprophytic nutrition Organisms such as many of the *fungi*, obtain food from dead or decaying organic matter e.g. rotting wood. Some food substances must first be broken down by enzymes sent outside the organism. This is *extracellular* digestion.

Food is necessary for the following reasons.
a To provide material for growth of new tissues and replacement of worn out or damaged ones;
b To be oxidised in internal respiration, liberating energy which can be used for the other life processes;
c To provide material for all the chemical processes, and protect against deficiency diseases.

Classes of food

CARBOHYDRATES

Compounds containing the elements carbon, hydrogen and oxygen, with the ratio of hydrogen to oxygen always 2:1 as in H_2O. Examples: glucose sugar $C_6H_{12}O_6$, cane sugar (sucrose) $C_{12}H_{22}O_{11}$, starch $(C_6H_{10}O_5)_n$.

Foods rich in carbohydrates: Sugar and foods containing it: e.g. jam, honey, fruit, milk, foods containing starch e.g. bread, cakes, biscuits, potatoes, rice, cereals etc.

Value of carbohydrates: Energy giving. 1 g carbohydrate gives 17·2 Joules of energy when oxidised. Excess stored as *glycogen* in the liver and muscles of mammals. Further excess is converted to fat and stored under the skin and around the internal organs.

FATS

Compounds containing carbon, hydrogen and oxygen but the proportion of oxygen is less than that in carbohydrates. Example: Olive oil $C_{57}H_{104}O_6$.

Foods rich in fats: Butter, margarine, lard, milk, cream, cheese, nuts, fat meat, fried foods.

Value of fats: Energy giving. More per g than carbohydrates. 1 g fat gives 39 Joules when oxidised. Excess stored under skin and around internal organs. Serves as heat insulation.

PROTEIN

Complex compounds built of units called *amino acids*, containing carbon, hydrogen, nitrogen, sulphur and often phosphorus. Twenty-three amino acids are known to be important. Proteins containing most of them are *first class* proteins. Proteins containing only a few are *second class* proteins. Example: Insulin $C_{254}H_{377}O_{75}N_{65}S_6$.

Foods rich in protein: 1st Class – lean meat, fish, eggs, milk, cheese. 2nd Class – peas, beans, lentils, nuts.

Value of proteins: Built into new protoplasm and cells for growth and replacement. It cannot be stored. Excess is oxidised to give energy. 1 g protein gives 17·2 Joules when oxidised. Remainder is formed into *urea* by the liver and sent to the kidneys to be excreted.

VITAMINS

Complex chemical compounds with no energy value. Essential in small quantities for the normal chemical activities of the body. If a vitamin is deficient in the diet, a deficiency disease results. The most important vitamins are summarized below:

Vitamin A

Foods rich in the vitamin: Green vegetables, carrots, milk, butter, fish liver oils, egg yolk, papayas, liver.

Functions: Keeps mucous membranes healthy e.g. cornea and respiratory tract. Forms colouring pigments of eye and skin. Promotes growth of the young.

Results of deficiency: Reduced resistance to disease. Skin dry and scaly. Mucous membranes dry. Night blindness. Retarded growth.

Further notes: Fat soluble. Not destroyed by heating.

Vitamin B_1

Foods rich in the vitamin: Yeast and yeast extract e.g. pigs liver, egg yolk, wheat germ e.g. wholemeal bread and cereals and unpolished rice.

Functions: Necessary for general body metabolism and good nervous system.

Results of deficiency: Digestive disorders, loss of appetite, muscular wasting and nervous disorders leading to beri beri.

Further notes: Destroyed by heat. Water soluble.

B_2 Complex (mixture of at least 9 substances)

Foods rich in the vitamin: Milk, wheat germ, lean meat, liver, eggs, peas, beans, fish.

Functions: Necessary for normal growth and nutrition.

Results of deficiency: Dermatitis. Nervous disorders, leading to Pellagra.

Further notes: Water soluble.

Vitamin C

Foods rich in the vitamin: Blackcurrants, citrus fruits, tomatoes, fresh green vegetables.

Functions: Growth of good teeth, gums and bones. Strong blood capillaries. Wound repair.

Results of deficiency: Reduced resistance to infection. Poor healing of wounds. Haemorrhages of the skin, mouth and gums. Leading to scurvy.

Further notes: Easily destroyed by long storage, and heat. Water soluble.

Vitamin D

Foods rich in the vitamin: Milk, eggs, cream, margarine, fish liver oils.
Functions: Necessary for bone formation, teeth and nails.

Results of deficiency: Malformed bones and teeth. Rickets.

Further notes: Fat soluble. Made by natural fats under the skin in sunlight.

Vitamin E

Foods rich in the vitamin: Eggs, wheat germ, liver, lettuce, water-cress.

Functions: Formation of sex cells. Correct functioning of placenta.

Results of deficiency: Sterility.

Further notes: Fat soluble. Only proved in rats, cats and dogs, not in humans.

MINERAL SALTS

Certain elements are needed in small quantities for chemical processes. It is taken into both animals and plants in the form of soluble mineral salts. Plants make their own carbohydrates and fats, and take in mineral salts to combine with them to form proteins and vitamins.
The main elements are shown in the table below.

Element	Source in mammalian diet	Function in mammals	Result of deficiency in mammals	Source in plant diet	Function in plants	Result of deficiency in plants
Iron	Green vegetables, liver, lean meat, eggs	Making haemoglobin	Anaemia	Soil	Must be present before chlorophyll can be formed	Poor growth; yellow leaves
Calcium	Milk, eggs, green vegetables, tinned fish	Strengthening bones, teeth and nails; blood clotting	Rickets	Soil	Functioning of cell walls	Stunted growth
Phosphorus	Milk, eggs, green vegetables, tinned fish	Strengthening bones, teeth and nails	Rickets	Soil	Making nuclei	Thin weak shoots
Sodium and chlorine	Table salt, green vegetables	Maintaining correct composition of body fluids	(Rarely deficient) Poor digestion	Soil	Not essential	Growth slightly less than normal
Potassium	Green vegetables	Maintaining correct composition of body fluids; cell division	Poor growth; kidney disorders	Soil	Making chlorophyll; cell division	Poor growth; yellow leaves with dead spots
Magnesium	Lean meat, wholemeal, bread and cereals	Functioning of nerves and muscles	Convulsions	Soil	Making chlorophyll	Mottled yellow leaves

Table showing main elements needed by plants and animals

WATER

Essential for the following reasons:

1. Forms part of the structure of protoplasm.
2. Acts as a solvent, as all chemical processes take place in solution in the cells.
3. Forms the main part of body fluids such as blood and sap which transport food substances, dissolved gases and hormones etc. around the animal or plant.
4. Forms secretions such as nectar, digestive juices, sweat etc.
5. Must replace that lost in transpiration, sweating and urinating etc. as these processes are vital to life.

Plants obtain water from the soil.
Animals obtain water mainly from plants e.g. fruit and vegetables, or by drinking it directly.

Food tests

TEST FOR STARCH

Method: Shake starch powder, with a little water, in a test tube. Add a few drops of dilute iodine solution.

Result: Blue-black colour.

Conclusion: Starch is present.

TEST FOR REDUCING SUGARS e.g. Glucose

Method: Shake a little glucose with water in a test tube. Add a few drops of Fehling's solutions A and B in equal amounts and boil.

Result: Brick red precipitate.

Conclusion: A reducing sugar is present.

TEST FOR PROTEIN

Method: Shake some egg white with a little water in a test tube. Add a few drops of Millon's Reagent and boil.

Result: A pink precipitate.

Conclusion: Protein is present.

TEST FOR FATS

If fat is obviously present the food leaves a translucent mark on white paper. To find its presence in small amounts the food must be ground up with a fat solvent e.g. ether or carbon tetrachloride, and when this is poured onto paper it evaporates. If a translucent mark is left fat is present.

Nutrition of green plants

PHOTOSYNTHESIS

This is the process by which *green plants build up carbohydrates from water and carbon dioxide, using light energy from sunlight and using chlorophyll.* Oxygen is given off as a by-product. This process takes place mainly in the leaves which are adapted for this by their *form* and *internal structure.*

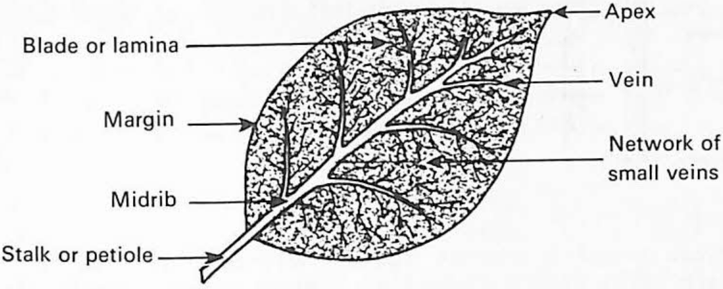


fig. 5 General leaf form

Form

The flattened thin blade is adapted to absorb sunlight and carbon dioxide.

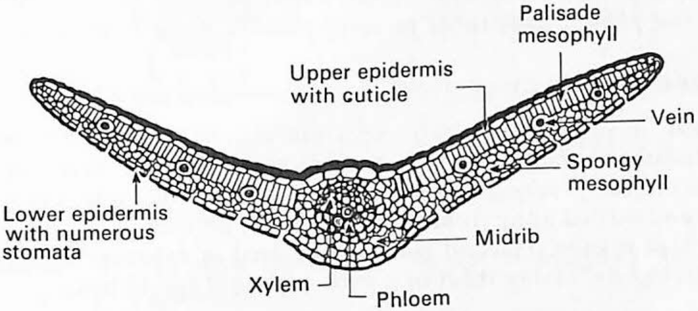
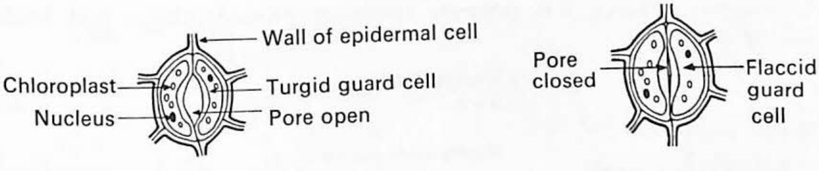

Palisade mesophyll
Upper epidermis with cuticle
Vein
Spongy mesophyll
Lower epidermis with numerous stomata
Midrib
Xylem
Phloem

fig. 6 Section through a leaf

Internal structure

The *epidermis* is a single layer of cells with no chloroplasts. Only the *guard cells* of the *stomata* have chloroplasts containing chlorophyll.



Stoma open

Stoma closed

fig. 7

Gases pass in and out of the stomata when open. They are more frequent on the lower surface.

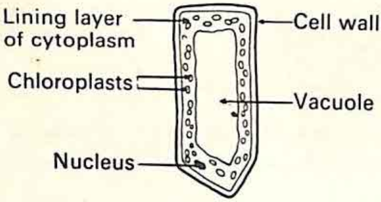


fig. 8 Single palisade cell

The *palisade mesophyll* contains regularly arranged cells with many chloroplasts. They absorb most of the sunlight passing through the transparent epidermis.

The *spongy mesophyll* contains cells which do not fit closely together and have air spaces between them through which gases circulate. They contain fewer chloroplasts than palisade cells.

The *vascular bundles* contain *xylem* vessels to carry water to the leaf cells, and *phloem* seive tubes to carry manufactured foods away.

EXPERIMENTS ON PHOTOSYNTHESIS

If sugar is produced quickly, enzymes change it to starch which accumulates in the leaves, so a positive test for starch indicates that photosynthesis is taking place. In darkness all the starch is changed to sugar and carried away from the leaves in the phloem to active regions or storage organs. Thus all plants to be used in experiments must be de-starched by leaving them in a dark cupboard for 48 hours.

Experiment 1: To test a leaf for starch

Method: Detach a leaf and dip it in boiling water to kill the protoplasm. Transfer it to methylated spirits and boil over a water bath until all the chlorophyll has been dissolved and the leaf is white. Soften the leaf by dipping it into boiling water again, then place it on a white tile and drop iodine solution onto it.

Result: The leaf turned blue-black.

Conclusion: Starch was present, therefore photosynthesis had been taking place.

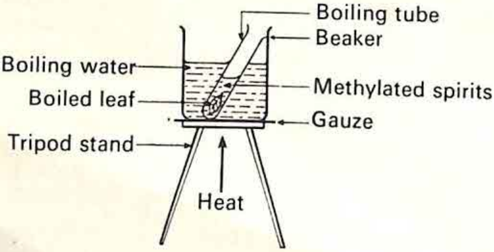


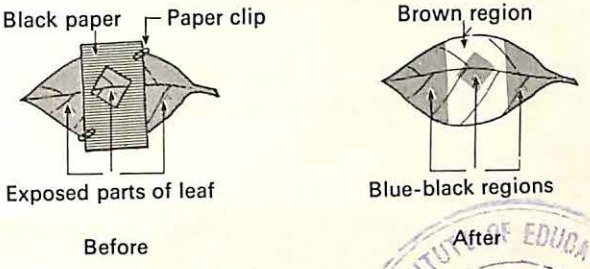
fig. 9 Removing chlorophyll

Experiment 2: To show that sunlight is necessary for photosynthesis

Method: Take a small de-starched Bougainvillea plant and fix pieces of tinfoil or dark paper with a pattern cut in, onto both surfaces of one leaf. Leave the plant in bright sunlight for about four hours, then detach the leaf and test it for a starch. Detach another leaf and test it as a control.

Result: The control leaf turned blue-black. The leaf that had been covered turned blue-black only in the regions left exposed to light.

Conclusion: Starch is only formed in regions exposed to light, therefore photosynthesis only takes place in the light.



Before

After

fig. 10 To show light is necessary

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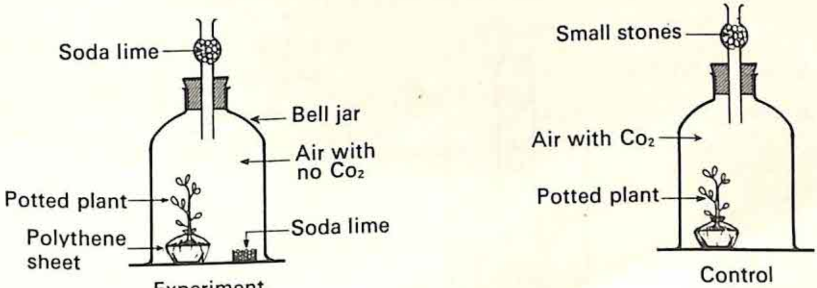
Experiment 3: To show that carbon dioxide is necessary for photosynthesis

Method: Place two de-starched, potted Begonia plants under bell jars and cover the pots with polythene to prevent any gases, given off from the organisms in the soil, interfering with the experiment. Allow air to enter the control jar, but remove all carbon dioxide from the air entering the other jar by using soda lime as shown in fig. 11. Leave both jars in bright sunlight for about four hours, then test a leaf from each for starch.



Experiment

Control

fig. 11 To show that carbon dioxide is necessary

Result: The leaf from the control plant turned blue-black, but the leaf from the plant without carbon dioxide did not.

Conclusion: Starch is not formed in the absence of carbon dioxide, therefore carbon dioxide is necessary for photosynthesis.

Experiment 4: To show that chlorophyll is necessary for photosynthesis
Method: Take a plant with variegated leaves which have chlorophyll in some regions only e.g. Tradescantia. Leave it in a strong sunlight for about four hours. Detach a leaf, draw a careful diagram to show the distribution of chlorophyll, then test for starch.

Result: Only the region that was originally green turned blue-black with iodine.

Conclusion: Starch is only formed in the green parts of a leaf, therefore chlorophyll is necessary for photosynthesis.

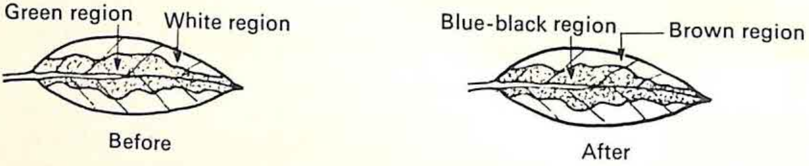


fig. 12 To show that chlorophyll is necessary

Experiment 5: To show that oxygen is given off during photosynthesis
Method: Take some pond weed and place it under an inverted funnel in a beaker of water. Place a test tube full of water over the funnel stem and leave the apparatus in bright sunlight.

Result: Bubbles were given off from the pond weed and collected in the test tube. When enough gas had collected it was shown to make a glowing splint burst into flame.

Conclusion: Oxygen is given off during photosynthesis.

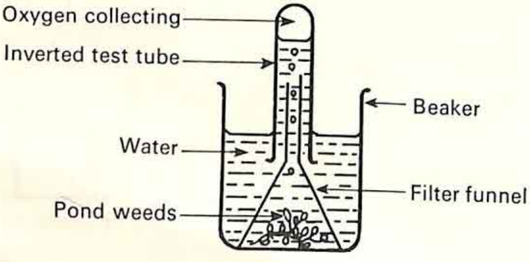


fig. 13 To show that oxygen is given off

Mineral nutrition in plants

A plant can only make carbohydrates by photosynthesis. Essential elements such as nitrogen and sulphur must be absorbed in the form of soluble mineral salts to combine with carbohydrates to make proteins.

Experiment: To find the main elements necessary for plant growth

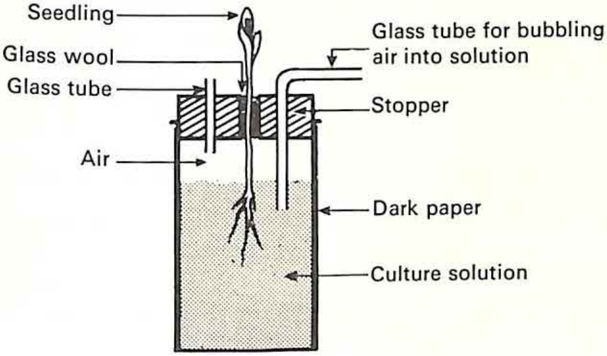


fig. 14 Water culture jar

Method: Set up seven water cultures using the apparatus shown in fig. 14. All jars should be:

a sterilized;
b blacked out with dark paper to prevent the growth of algae;
c filled with a culture solution as follows:

Jar 1 Normal culture containing:
2 g potassium nitrate
$\frac{1}{2}$ g calcium sulphate
$\frac{1}{2}$ g ferric sulphate
$\frac{1}{2}$ g magnesium sulphate

dissolved in 2 litres distilled water.

Jar 2 Lacking nitrate
Jar 3 Lacking potassium
Jar 4 Lacking phosphate
Jar 5 Lacking calcium
Jar 6 Lacking iron
Jar 7 Containing distilled water

A seedling of the same type, age and size, with well washed roots should be placed in each jar, and supported by glass wool. Air should be bubbled in each day, and the jars should be left in the same conditions of light and temperature for two or three weeks.

Result: The seedling in Jar 1 is large, and healthy with dark green leaves. In Jar 2, the seedling had poor growth and dried-up pale green leaves. In Jars 3 to 6: see the results in the mineral chart on page 7. In Jar 7 the seedling was dead.

Conclusion: Normal growth only takes place when mineral salts containing the elements nitrogen, potassium, sulphur, calcium, iron, phosphorus and magnesium are present.

NUTRITION OF A SAPROPHYTE

Mucor (pinmould) is a *Saprophytic fungus* found growing on decaying fruit, bread, horse manure, etc.

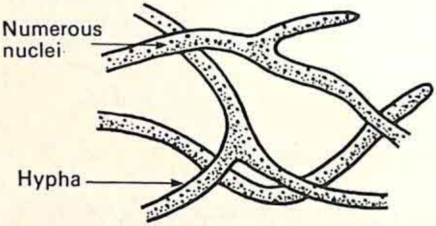


fig. 15 a Part of mycelium of mucor

Structure: Plant body consists of a dense white mass of hyphae forming a mycelium; not divided into cells. There is a central vacuole and the cytoplasm containing many nuclei, forms a layer beneath the cell wall. No chlorophyll present.

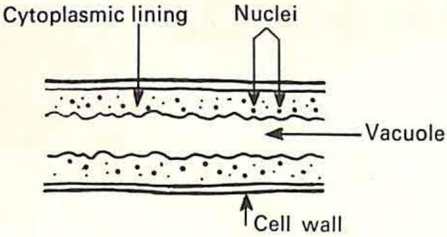


fig. 15 b L.S. part of hypha

Nutrition: Feeds on dead and decaying organic matter. Enzymes secreted from tips of hyphae digest the food externally (extracellular digestion), and the simple soluble substances are absorbed into the hyphae. Oil droplets form a food reserve.

Nutrition of animals

In all animals this takes place in four stages:

1 **Ingestion** The taking in of food.

2 **Digestion** The breaking down of food into simple soluble substances. This is brought about by enzymes which are made by living cells, and have the following properties:

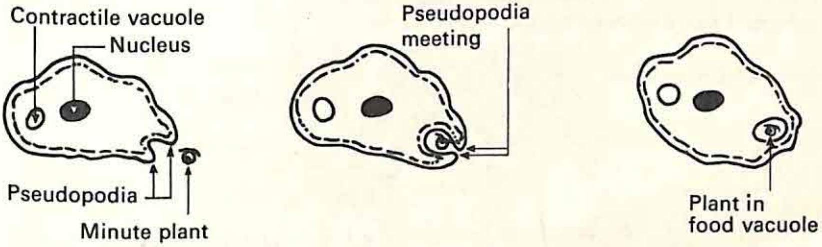
a they are *organic catalysts*, speeding the rate of a reaction without being used up;
b they are *specific*, acting only on one type of substance or in one type of reaction;
c they are *potent*, as very small quantities can change large quantities of other substances;
d they are *destroyed by boiling*;
e they work best between 30 deg. C and 40 deg. C;
f they are sensitive to *acidity*. Some need an acid medium and some need an alkaline medium.

3 **Absorption** The absorbing of the soluble digested food materials into the body.

4 **Assimilation** The using of the food materials by the body.

NUTRITION OF AMOEBA

Ingestion of a minute water plant



a Pseudopodia forming **b** Pseudopodia trapping plant **c** Food vacuole formed

fig. 16 Ingestion of a minute water plant

Digestion This is carried out by enzymes made in the protoplasm and poured into the food vacuoles. The soluble food materials are then **absorbed** and **assimilated**.

NUTRITION IN A MAMMAL e.g. Man

Takes place in the *alimentary canal.*

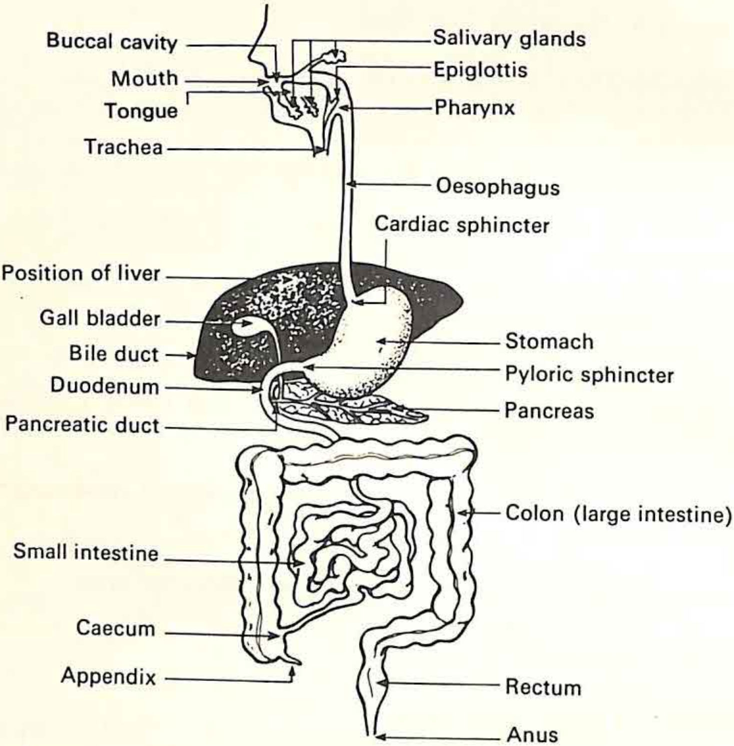


fig. 17 Alimentary canal and associated glands of man

Ingestion

Food is taken into the mouth and masticated by the teeth. Teeth are adapted for different tasks.

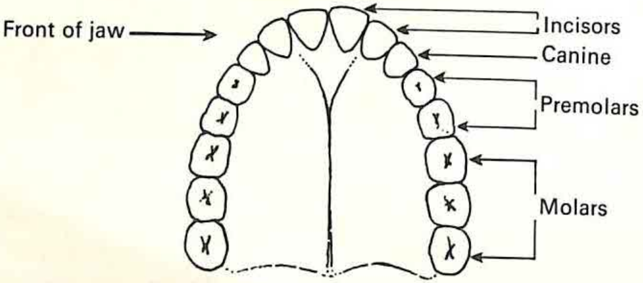
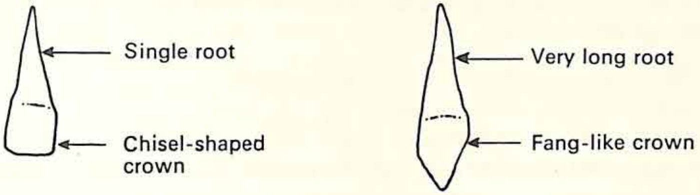


fig. 18 Arrangement of teeth in man

a Incisor b Canine



c Premolar d Molar

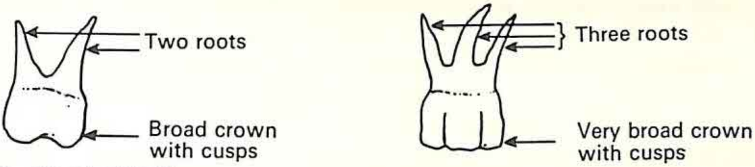


fig. 19 Types of teeth

Incisors: Chisel shaped. One root. Four in each jaw. Biting and cutting.

Canines: Pointed, fang-like. One long root. Four in each jaw. Gripping and tearing meat.

Premolars: Ridged surface of cusps. Two roots. Four in each jaw. Chewing and grinding.

Molars: Ridged surface of cusps. Three roots. Larger than premolars. Six in each jaw. Chewing and grinding.

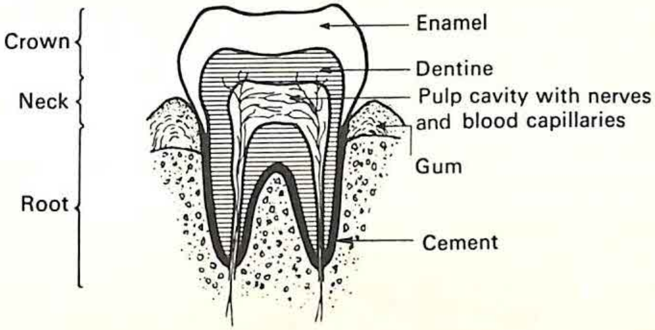


fig. 20 Section through a molar

Tooth structure: The *crown* is the visible part outside the gum. The *root* is set in the jaw bone. *Enamel* covers the crown. Made of calcium salts. Hard masticating surface. *Dentine* is hard but softer than enamel. Gives the shape to the tooth. Protects *pulp cavity*. Pulp cavity is in the centre of tooth. Containing blood capillaries to bring food and oxygen, and sensory nerve endings. *Cement* covers the tooth in the gum.

Digestion

In the mouth, saliva is poured onto the food from three pairs of salivary glands. Saliva:

a contains mucus which lubricates the food;
b dissolves a little food, bringing out the taste;
c contains the enzyme *ptyalin* which begins the digestion of cooked starch to the simple sugar maltose. Neutral or slightly alkaline medium.

Digestion is aided by mastication and by the tongue which moves the food about and finally rolls it into a *bolus* and pushes it to the back of the mouth, where it is swallowed, and passes down the *oesophagus* by *peristalsis*. Peristalsis is a muscular action pushing the food along the alimentary canal. No digestion takes place in the oesophagus.

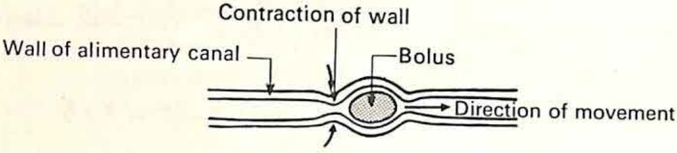


fig. 21 Peristalsis

Digestion in the stomach: Glands in the stomach wall produce:
a *Gastric juice* containing the enzymes *pepsin* and *rennin*. Pepsin splits proteins into *proteoses* and *peptones*. Rennin occurs in young mammals and clots milk by changing the soluble milk protein *caseinogen* to insoluble *casein* so it stays in the stomach long enough for pepsin to work on it.
b *Hydrochloric acid* which is dilute (0.5%). It provides the acid medium for pepsin. It kills bacteria taken in with food. It stops the action of the alkaline saliva. Food is churned in the stomach and retained by the closure of two rings of muscle at either end, the *cardiac sphincter* and the *pyloric sphincter*. It remains inside for 1 to 4 hours, depending on the protein present. Then in the form of a semi-liquid *chyme* it is squirted through the pyloric sphincter into the *duodenum*.

Digestion in the duodenum: This is the first loop of the small intestine (25 cm to 30 cm). Three juices are poured onto the food:
i *Pancreatic* juice from the pancreas. An alkaline juice containing three enzymes. *Amylase* splits starch (uncooked) into maltose. *Lipase* splits fats into fatty acids and glycerol. *Trypsin* splits proteins and proteoses into peptones, and some peptones into amino acids.
ii *Bile* made in the liver, stored in the gall bladder and passed down the bile duct. Greenish yellow, containing bile pigments and sodium bicarbonate which helps make the intestine alkaline. Contains no enzymes but bile salts emulsify fats, forming suspension of droplets which have a large surface area, so are more easily attacked by lipase in the pancreatic juice.

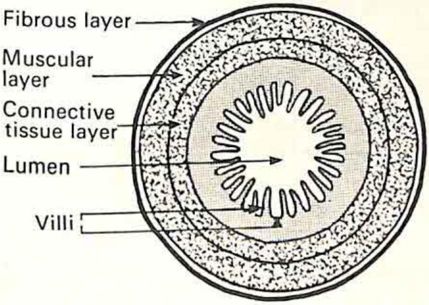
iii *Intestinal* juice (succus entericus). Alkaline. Made in glands lining the walls in the duodenum and the rest of the small intestine. Contains enzymes which completely finish digestion, the main ones being:
Enterokinase changes *typsinogen* to *trypsin* which is sent to the pancreas.
Erepsin finishes the breakdown of all peptones to amino acids.
Maltase changes maltose to glucose.

Digestion in the small intestine: Digestion is completed in the small intestine by the enzymes in the intestinal juice.
All *carbohydrates* are now in the form of simple sugars e.g. glucose.
All *proteins* are now in the form of amino acids.
All *fats* are now in the form of fatty acids and glycerol.
Mineral salts and *vitamins* do not have to be digested as they are already soluble.

Absorption

The digested foods are absorbed through the walls of the small intestine into the blood. Only alcohol is absorbed through the stomach walls. The small intestine is adapted by:

a its length – 7 m.



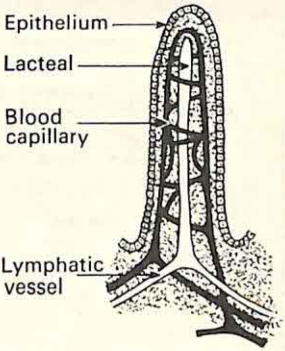


fig. 22 T.S. small intestine to show villi

fig. 23 L.S. single villus

b its lining is folded into numerous finger-like projections called *villi* which provide an enormous surface area. Each villus has a very thin lining – *epithelium*, and contains a network of blood capillaries and a central lymph vessel called a *lacteal*. All digested foods except fats diffuse through into the blood capillaries, which join up to form the hepatic portal vein taking the foods to the liver.

Fatty acids and glycerol pass into the lacteals where they recombine to form fats which are carried in the lymph and eventually passed into the blood through the veins at the base of the neck.

Assimilation

Glucose is sent from the liver to the cells of the body where it is oxidised to release energy in internal respiration. Excess is stored in the liver and muscles as the insoluble animal starch *glycogen*. Storage governed by the hormone *insulin* sent from the pancreas. Further excess is stored as fat under the skin and around the internal organs.

Amino acids are sent from the liver to build new protoplasm for growth, repair and replacement of tissues. Excess is broken down by the liver to form *urea* which is sent to the kidneys to be excreted. Fats are oxidised to release energy and excess is stored.

Functions of the large intestine (colon)

Undigested food material, some mineral salts, water, dead cells, mucus and bacteria pass along by peristalsis. Water and mineral salts are absorbed through the walls. The remainder is passed out through the anus as faeces.

Table showing summary of digestion in Man

Regions of the alimentary canal	Digestive glands	Digestive juices	Enzymes	Substances acted upon	Substances produced
Mouth	Salivary glands	Saliva (slightly alkaline)	Ptyalin	Cooked starch	Maltose
Stomach	Gastric glands in lining of stomach	Gastric juice (.5% Hydrochloric acid also secreted)	Pepsin	Proteins	Proteoses and peptones
			Rennin	Caseinogen (milk protein)	Casein (clotted milk)
Duodenum	Pancreas	Pancreatic juice (alkaline)	Amylase	Starch	Maltose
			Lipase	Fats	Fatty acids and glycerol
			Trypsin	Proteins and proteoses	Peptones and amino acids
	Liver	Bile (alkaline)	None	Fats	Emulsion of fats to help action of lipase
Ileum	Glands in lining of small intestine	Intestinal juice (Succus entericus) (alkaline)	Erepsin	Peptones	Amino acids
			Maltase	Maltose	Glucose
			Invertase	Sucrose	Glucose and fructose
			Plus other enzymes to finish digestion		

3 Interdependency

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All animals depend directly or indirectly on green plants for their food, as green plants can build up their own food from simple substances by photosynthesis.

Herbivorous animals eat plants directly e.g. a rabbit eats grass.

Carnivorous animals eat smaller animals which either feed on plants or on even smaller animals which eat plants. This is a food chain e.g. wheat ⟶ mouse ⟶ cat

Balance of nature: If one of the animals or plants in a food chain becomes scarce all the others are affected e.g. if all cats in one area died, the mice would increase at the expense of the wheat. If all mice died instead, the wheat would flourish, but the cats would attack other animals such as birds or rats for food, or they would die.

Relationships beneficial to man

The carbon cycle: All energy is dependent on the carbon compounds formed by photosynthesis. The circulation of carbon between living organisms dependent on each other, and the carbon dioxide in the air is the carbon cycle.

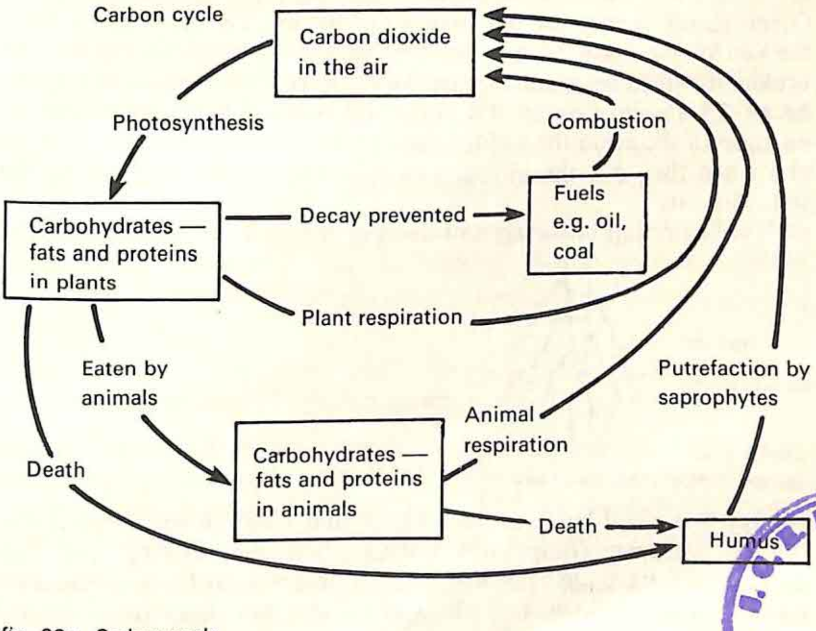
Carbon cycle
Carbon dioxide in the air
Photosynthesis
Combustion
Fuels e.g. oil, coal
Carbohydrates — fats and proteins in plants
Decay prevented
Plant respiration
Eaten by animals
Putrefaction by saprophytes
Animal respiration
Death
Carbohydrates — fats and proteins in animals
Death
Humus

fig. 23a Carbon cycle

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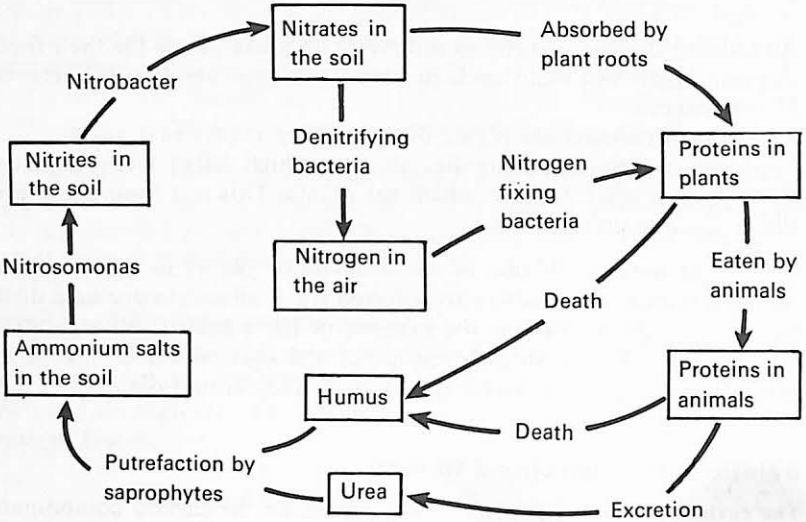


fig. 23 b Nitrogen cycle

The nitrogen cycle: This is the circulation of nitrogen between living organisms and the soil. Nitrogen is necessary for protein formation. Green plants cannot use the nitrogen of the air, but must take it from the soil in the form of *nitrates*. Nitrogen compounds in the soil are broken down to form nitrates by the bacteria *Nitrosomonas* and *Nitrobacter*. This is *nitrification*. Two other types of soil bacteria can use the nitrogen of the air in the soil for their proteins. This is *nitrogen fixation*, and when they die, the nitrogen compounds become available to the soil. They are:

a bacteria living in the root nodules of plants in the pea family;

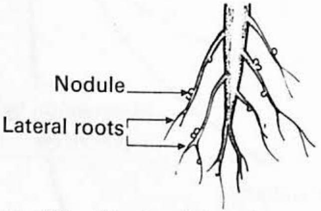


fig. 24 Root nodules of pea

b free-living soil bacteria *Azotobacter* and *Clostridium*. The soil also obtains nitrogen compounds during lightning. During the high energy discharge, nitrogen and oxygen combine to form compounds that are washed down into the soil by the rain. Loss from the soil occurs when *denitrifying bacteria* break down some nitrogen compounds and release nitrogen gas back into the air.

Relationships harmful to man

Disease: Some germs or *micro-organisms* are parasites, living on animal or plant hosts, causing disease. Four main types:

Bacteria
Viruses
Fungi
Protozoa

Bacteria: Found universally in soil, water, air and living organisms. Unicellular. Microscopic. Smallest $\frac{1}{1000}$ mm diameter.

Various shapes.

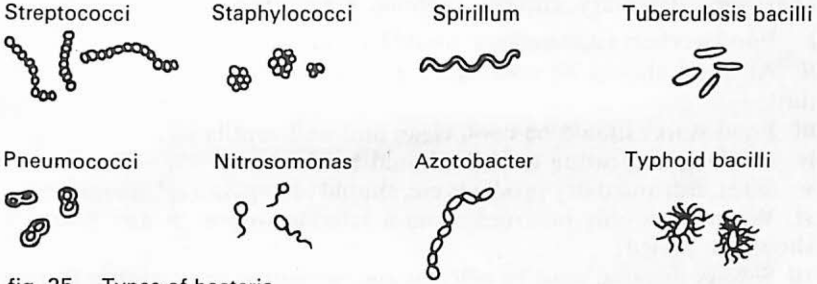


fig. 25 Types of bacteria

Require moisture, a suitable temperature and food for growth. Some need oxygen, others do not. Can form resistant spores when conditions unsuitable. Reproduce quickly by simple *binary fission*. Produce poisons called *toxins*.

Diseases caused: Examples: tetanus, tuberculosis, boils.

Viruses: Only seen with powerful electron microscope. Smallest $\frac{1}{2\,500\,000}$ mm. Unicellular. Various shapes. Only reproduce inside their hosts. Cannot form spores. Have been isolated from some hosts in crystal form.

Diseases caused: Examples: Smallpox, foot and mouth disease of cattle, tobacco mosaic of tobacco plant.

Fungi: Plants without chlorophyll. Body unicellular or of branching *hyphae*. Require moisture, a suitable temperature and food for growth. Reproduce sexually and asexually to form large numbers of spores. *Diseases caused*: Examples: Athletes foot, ringworm, potato blight.

Protozoa: Microscopic unicellular animals. Require moisture, a suitable temperature, food and oxygen for growth. Can form resistant cysts. Reproduce by binary fission.
Diseases caused: Examples: Malaria, African sleeping sickness.

Transmission and control of disease

1 *Air-borne diseases*: Breathed in from the infected person either directly, or indirectly as infected droplets or dried to form dust. Examples of air-borne diseases: Pneumonia, influenza, diphtheria. Prevention:

i Prevention of overcrowding;
ii Removal of dust;
iii Good ventilation;
iv Trapping coughs and sneezes in a disposable handkerchief;
v Isolation of highly infectious persons;
vi Avoid spitting.

2 *Food and water borne diseases*: Taken into the alimentary canal in infected food or water. Examples of diseases spread this way: Diarrhoea, dysentery, cholera, typhoid. Prevention:

i Food workers and handlers should have clean hands and clothing;
ii All food should be covered to prevent contamination by flies or dust;
iii Food stores should be cool, clean and well ventilated;
iv Cooking and eating utensils should be clean;
v Meat, fish and dairy products etc. should be kept in a refrigerator;
vi Water must only be drunk from a reliable source. If any doubt it should be boiled;
vii Sewage disposal must be efficient and prevented from contaminating water supplies.

3 *Contact diseases*: Spread by direct contact with an infected person or objects used by the infected person e.g. books, towels, toys, cutlery etc. Examples of contact diseases: Ringworm, measles, tuberculosis. Prevention:

i Personal cleanliness;
ii Disinfection or burning of contaminated objects.

4 *Vector-borne diseases*: Insects, rats and mice etc. can carry disease organisms on or in their bodies and infect humans by contaminating food or biting the skin. Examples: Housefly transmits typhoid, cholera, dysentery etc. Female anopheles mosquito transmits malaria. Rats carry rat fleas which transmit bubonic plague. Prevention:

i Removal of dust, general cleanliness;
ii Cover all food;
iii Wrap waste food in newspaper before putting in the dustbin;
iv Dustbins should be disinfected frequently;
v Dustbin lids should be tightly fitting;
vi Dustbins should not be near the house;
vii Holes and cracks in walls and floors should be blocked;
viii All vectors should be killed.

Preventive measure against mosquitoes

a Mosquito nets should be used over beds and netting placed over windows and doors in malarial countries.

b Adult mosquitoes should be sprayed with insecticide and kept at bay with repellant creams and mosquito coils etc.

c Breeding places should be removed. As mosquitoes lay eggs on stagnant water, and the larvae and pupae hang from the surface film by breathing tubes, all stagnant water e.g. ponds and marshes etc. should be drained.

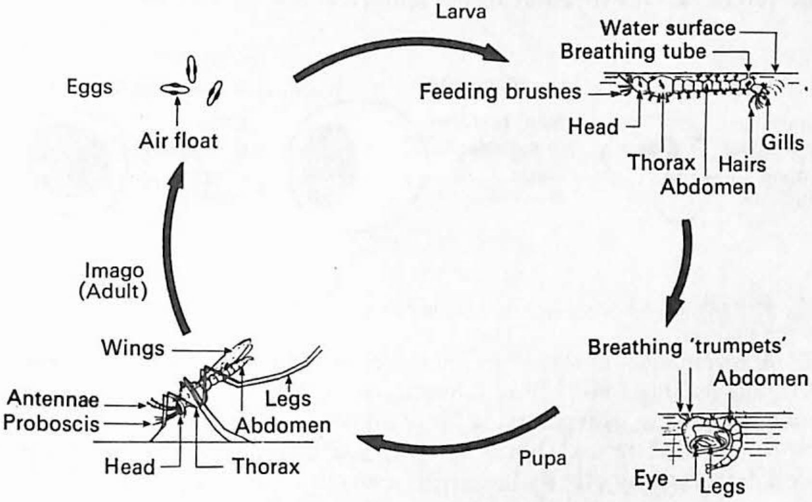


fig. 26 Life cycle of anopheles mosquito

d If standing water cannot be drained, the water should be sprayed with oil to block the breathing tubes and lower the surface tension so the larvae and pupae are killed.

e Preventive drugs containing quinine e.g. paludrine should be taken in malarial areas.

4 Transport of materials

Transport in mammals e.g. man

BLOOD AND THE CIRCULATORY SYSTEM OF MAN

Blood is the transport agent, pumped by the heart, carried around the body in blood vessels.

STRUCTURE OF BLOOD

Consists of fluid *plasma* containing red and white blood *corpuscles* and *platelets*.
Plasma: Pale yellow liquid, 90% water, 10% dissolved substances e.g. fats, amino acids, glucose, waste products, hormones, salts, blood proteins etc.

Red corpuscles: Disc shaped. Biconcave. Large surface area. No nucleus. Contain the red pigment haemoglobin. Average 5 million per mm^3 blood. Formed in the red marrow of the long-bones. Average life 110 days. Destroyed in spleen and liver. See fig. 2b page 2.

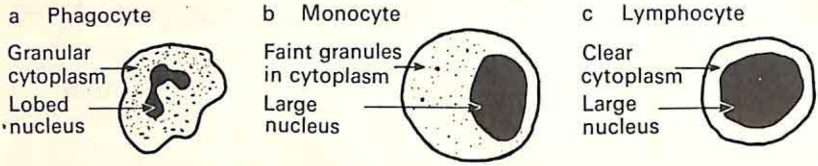


fig. 27 White blood corpuscles (Leucocytes)

White corpuscles: Larger than red but fewer. Ratio of 500 red: 1 white. Average 8000 per mm^3 blood. Some have a lobed nucleus and amoeboid movement, others have a large nucleus and no amoeboid movement. Formed in red bone marrow and lymph glands, worn-out ones destroyed by other white corpuscles.

Platelets: About 1/3 size of red corpuscles, no nucleus. Average 300 000 per mm^3 blood.

Functions of blood

1 *Transport*

a Oxygen is carried as oxyhaemoglobin in the red corpuscles, from the lungs to the tissues.

b Carbon dioxide is carried as sodium bicarbonate and carbonic acid dissolved in the plasma, from the tissues to the lungs.

c Food substances are carried in solution in the plasma from the small intestine to the tissues.

d Urea is carried in solution in the plasma from the liver to the kidneys to be excreted.

e Hormones are carried in solution in the plasma from the ductless glands to the tissues.

f Heat is produced by respiration in all tissues especially the liver and muscles and distributed evenly around the body (see further details on pages 28, 29 and 47).

2 *Defence against diseases*

a Antitoxins produced by white corpuscles to neutralise poisonous toxins formed by bacteria. Antibodies weaken or kill bacteria.

b White corpuscles called *phagocytes* ingest weakened bacteria.

c Clotting – Damaged tissues and platelets release the enzyme *thromboplastin* which acts on the blood protein *prothrombin.*

$$\text{prothrombin} \xrightarrow{\text{thromboplastin}} \text{thrombin}$$

Thrombin then acts on the blood protein *fibrinogen.*

$$\text{fibrinogen} \xrightarrow{\text{thrombin}} \text{fibrin}$$

Fibrin is insoluble and forms a network of threads over the wound. A clot forms which dries to a scab to prevent entry of germs until new skin grows.

Blood vessels

Arteries carry blood away from the heart. All carry oxygenated blood except the pulmonary artery taking blood to the lungs for oxygen. Thick, muscular, elastic walls for withstanding pressure and pumping the blood. No valves. Small lumen.

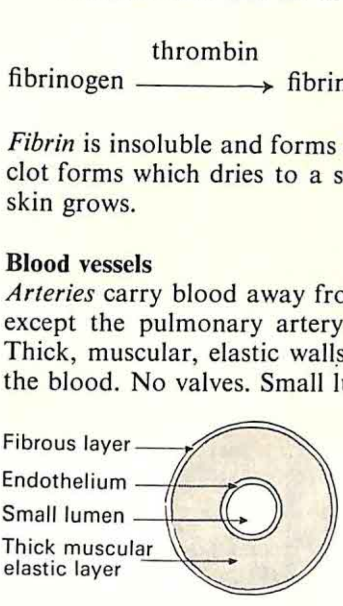


fig. 28 T.S. artery

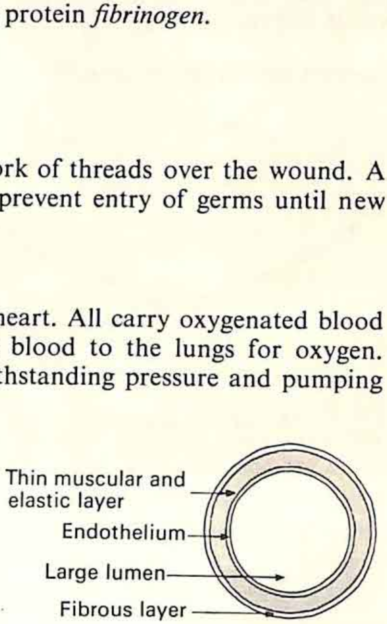


fig. 29 T.S. vein

Veins carry blood back to the heart. All carry deoxygenated blood except the pulmonary vein bringing blood back from the lungs. Thin walls with less muscle than arteries. Blood flows in veins. Pocket valves present to prevent backflow of blood. Large lumen.

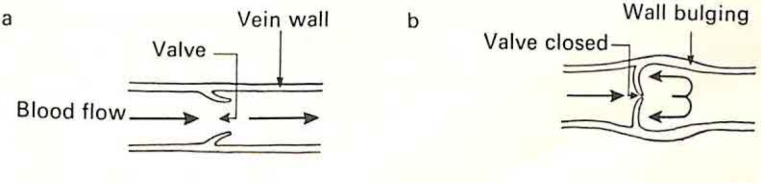


fig. 30 L.S. vein to show action of pocket valve

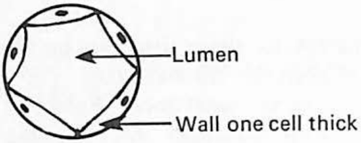
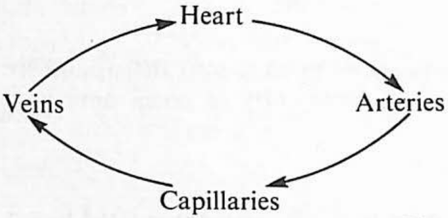


fig. 31 T.S. capillary

Capillaries form a network in the tissues joining arteries to veins. Minute. Hair-like. Walls only one-cell thick so substances diffuse between the blood and the surrounding tissues.

General circulation in vessels



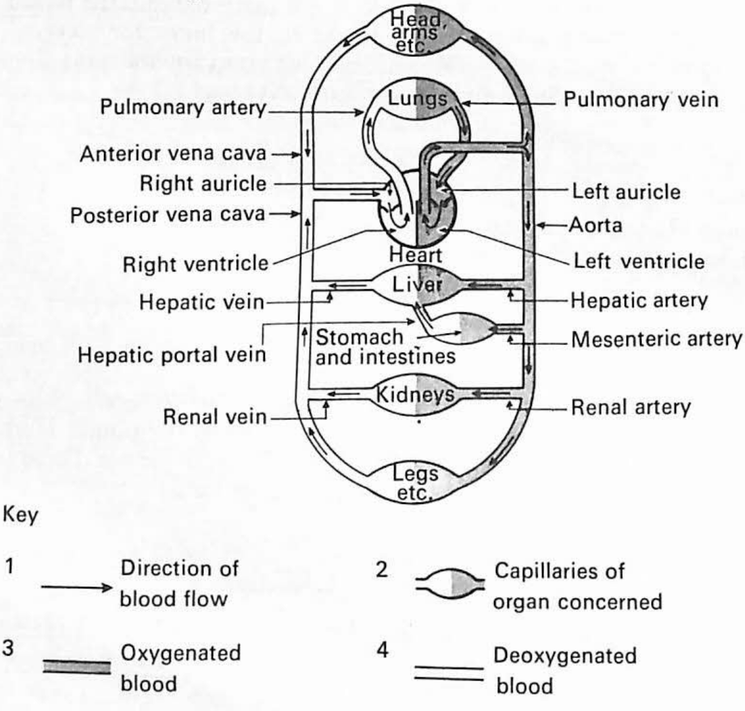


fig. 32 Diagram of blood circulation in a mammal

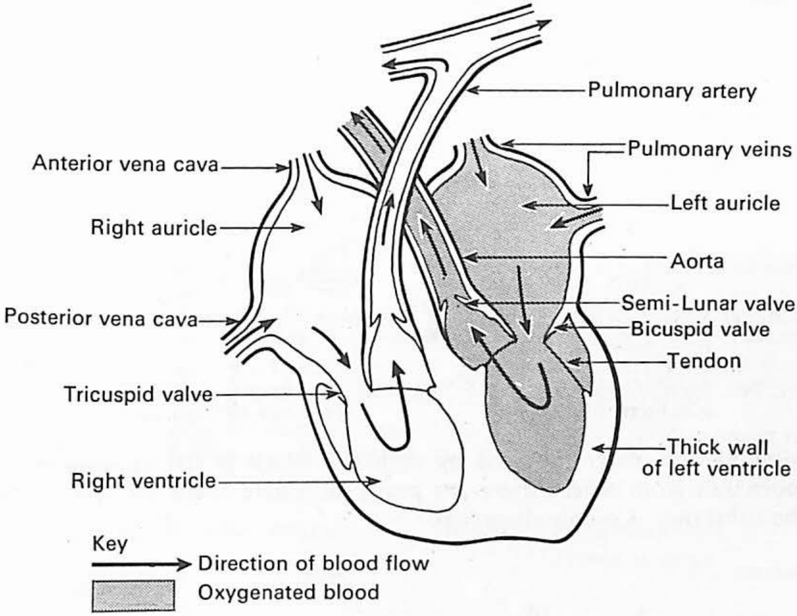


fig. 33 Diagram of L.S. mammalian heart

Deoxygenated blood from the body is brought back to the right side of the heart by the anterior and posterior vena cava veins. It flows into the right auricle and through to the right ventricle, and when the ventricle is nearly full the auricle contracts forcing more blood through. Then the ventricle contracts forcing closed the tricuspid valve leading back to the auricle and forcing open the semi-lunar valve leading to the pulmonary artery which carries the blood to the lungs. It is brought back in the pulmonary veins. This oxygenated blood passes through the left side of the heart in a similar fashion.

Note: Both auricles contract simultaneously and both ventricles contract simultaneously. The blood is pumped from the left ventricle into the aorta which sends it around the body to the tissues and organs where it loses its oxygen in the capillaries.

Practical work:

1 Observe blood circulation in the external gill or tail of a tadpole, using a powerful dissecting lens. Wrap its head in damp blotting paper.

2 Find the average rate of heart beat in a group of people by pressing the wrist pulse where an artery passes over a bone close to the skin. Repeat after exercise.

Transport in green plants

Water and dissolved substances enter the plant through the *root hairs* which are in close contact with the film of water around soil particles.

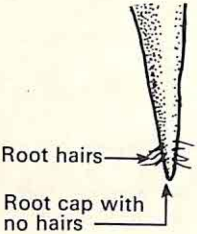


fig. 34 Tip of root showing root hairs

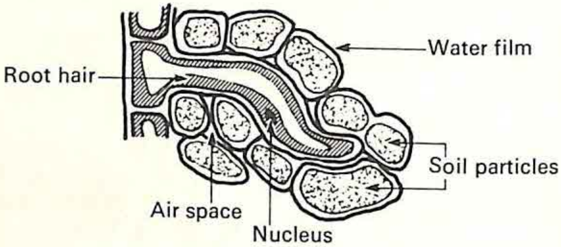


fig. 35 Relationship between root hair and soil particles

Mineral salts enter the root by *diffusion*, which is the movement of molecules from where there are many to where there are few, until the substance is evenly dispersed.

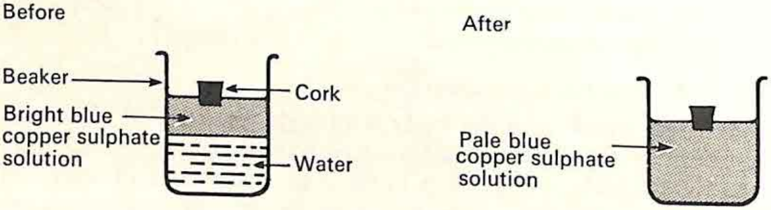

Before
After
Beaker
Cork
Bright blue copper sulphate solution
Water
Pale blue copper sulphate solution

fig. 36 Experiment to show diffusion

Experiment: To demonstrate diffusion
Method: Half fill a narrow beaker with water and float a cork on top. Slowly pour copper sulphate solution onto the cork to prevent much mixing. The blue copper sulphate solution forms a layer on top of the water. Leave for a week.

Result: The entire liquid is blue.

Conclusion: The molecules of copper sulphate have diffused into the water. Water enters the root by *osmosis* which is the passage of water from a weak solution to a strong solution across a semi-permeable membrane.

Experiment: To demonstrate osmosis
Method: Stretch a piece of pig's bladder across the mouth of a thistle funnel and tie on tightly. Pour strong sugar solution into the bulb until a little comes up the stem, and then hang it in a beaker of water as shown in fig. 37. Leave for 3 days.

Result: The solution in the thistle funnel had risen several inches up the stem.

Conclusion: Water has passed through the semi-permeable membrane into the strong solution.

Note: The passage of water would go on until the solutions on both sides of the membrane were of the same concentration.

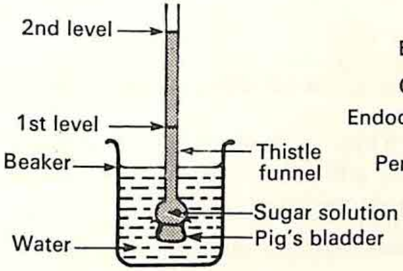


fig. 37 To demonstrate osmosis

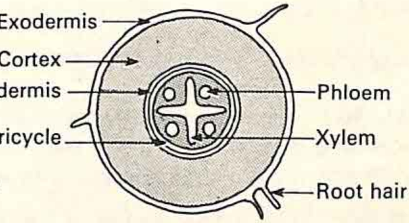


fig. 38 T.S. sunflower root to show structure

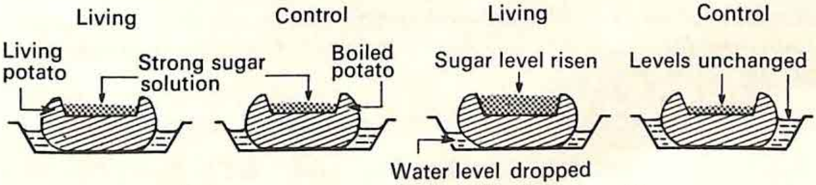
OSMOSIS IN LIVING TISSUES

The protoplasmic membrane of each cell acts as the semi-permeable membrane. When water is drawn into the root hair, it stretches, becoming turgid. It is now more dilute than the next cell of the root cortex so water passes through by osmosis. This process is repeated across the root until the water reaches the xylem.

Experiment: To demonstrate osmosis in living tissues
Method: Cut a potato in half. Boil one half and then scoop a hole in the top of each. Pour a little strong sugar solution in the holes, stand both in water in a shallow dish and leave.

Result: After a few hours the sugar solution in the living potato had filled the hole and flowed down the sides. The control remained unchanged.

Conclusion: Living protoplasm in the potato cells allowed osmosis to take place in every cell from the water to the strong solution.



a Before b After

fig. 39 Osmosis in living tissue

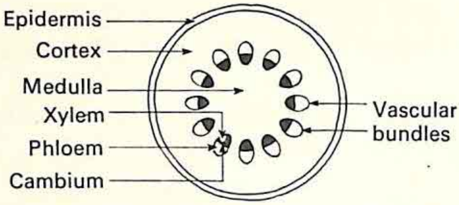


fig. 40 T.S. sunflower stem to show structure

Experiment: To show that water and dissolved substances pass up the xylem

Method: Place four leafy shoots with their cut ends in red ink solution. Remove one at 15 minute intervals, cut across the stem in several different regions and observe with a strong hand lens.

Result: The xylem region is stained red. The staining rises higher, the longer the shoots are left.

Conclusion: Red ink solution passes up the xylem of a stem. Water passes up the xylem by a combination of three forces:

Capillarity – the natural tendency of water to rise up narrow tubes.

Root pressure – a force from below.

Transpiration – a pull from above. This is the most important method. It is the evaporation of water vapour through the stomata of the leaves resulting in a stream of water being pulled from below to take its place. This is the transpiration stream.

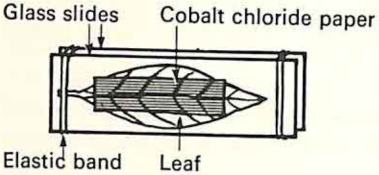


fig. 41 To find which surface of a leaf transpires most

Experiment: To find which surface of a leaf transpires most

Method: Place a leaf between two pieces of blue cobalt chloride paper and cover with glass slides as shown in fig. 41. Compare the time taken for the paper to turn pink.

Result: The paper on the lower surface turned pink first.

Conclusion: Transpiration is more rapid from the lower surface of a leaf.

Note: This is due to large numbers of stomata on the lower surface.

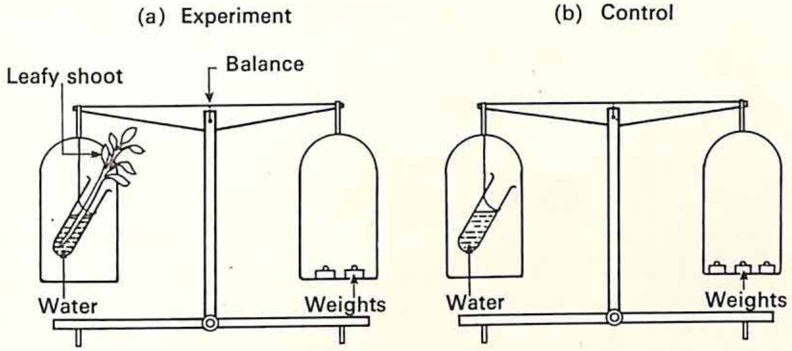


fig. 42 To show that a leafy shoot loses weight

Experiment: To show that a leafy shoot loses weight

Method: Set up the apparatus shown in fig. 42. Leave for two days.

Result: Both tubes had lost weight, but the one containing the leafy shoot had lost much more.

Conclusion: Both tubes lost weight due to evaporation of water, but the extra weight lost by the leafy shoot must have been due to water lost by transpiration.

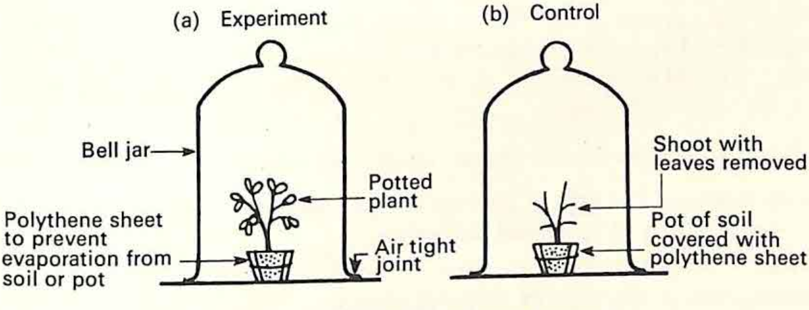

(a) Experiment
(b) Control
Bell jar
Potted plant
Polythene sheet to prevent evaporation from soil or pot
Air tight joint
Shoot with leaves removed
Pot of soil covered with polythene sheet

fig. 43 To show that a potted plant gives off water vapour

Experiment: To show that a potted plant (e.g. the balsam) gives off water vapour

Method: Set up the apparatus shown in fig. 43. Use a bell jar containing a plant from which all leaves had been removed as a control. Leave for one day.

Result: Drops of moisture condensed on the inside of the jar containing the leafy plant. These drops turned blue cobalt chloride paper pink. The control had no moisture.

Conclusion: Water vapour is given off from the leaves of a plant during transpiration.

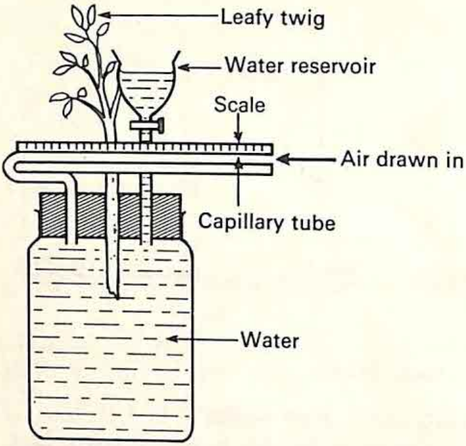


fig. 44 Potometer

Experiment: To compare the rate of transpiration under different conditions

Method: Fix a leafy twig (e.g. a balsam shoot) in a Potometer as shown in fig. 44.

Place the apparatus in different situations e.g. warm and wet, cold and windy etc. Leave for 15 minutes in each situation for the plant to adapt, then time the movement of air along the capillary tube. Reset the water in the tube each time.

Result: The air moved slower when cold, wet or still.

Conclusion: The rate of transpiration is faster in warm, dry or windy conditions due to increased evaporation.

Note: A potometer can also be used to compare the rates of transpiration in shoots of different plants.

5 Food storage organs

Storage organs in mammals

In mammals the main storage organ is the *liver*. Substances stored:
1 *Glycogen* formed from glucose;
2 *Iron* from the breakdown of old red blood corpuscles;
3 *Vitamins A*, B_{12} and *D*.

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Storage organs in plants

Green plants have various storage organs.

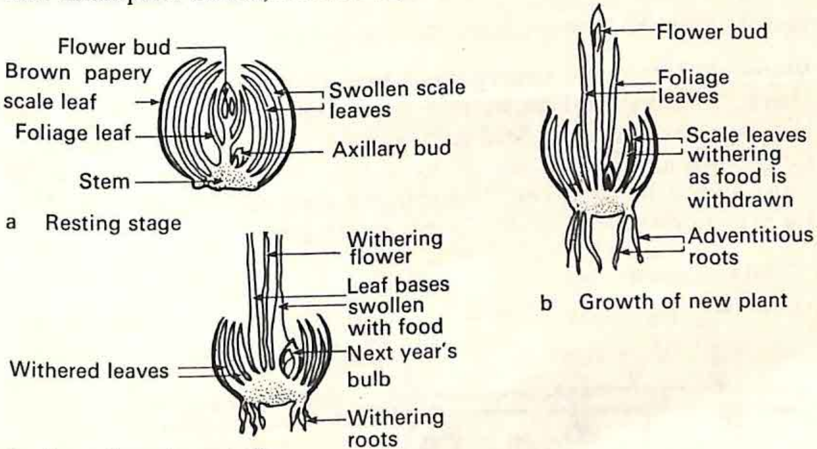
Annual plants have a life cycle lasting one year or less. They have food stores in their *seeds*.

Biennial plants have a life cycle lasting two years. They store food in an *underground organ* such as a *tap root* after the first year and then produce flowers and *seeds* the second year.

Perennial plants live for many years. Many produce underground storage organs each year: e.g. *bulbs*, *corms*, *tubers* and *rhizomes*. Some of these plants do not produce flowers and seeds for two or three years. As their storage organs have buds from which new plants develop, this type of reproduction is called *vegetative reproduction*.

Underground storage organs

Bulbs Compressed underground *shoot* with fleshy leaves swollen with *glucose*. Outer scale leaves dry and papery for protection. Adventitious roots. Terminal bud of compressed stem grows out to form new plant using stored food. Scale leaves shrink and wither as food is used. More food is sent down later by new plant, and the innermost axillary bud swells to form new bulb. Contractile roots pull new bulb down into soil. Examples: Onion, crimum lily.



a Resting stage

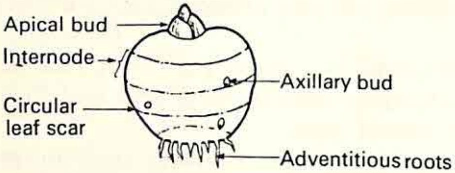
b Growth of new plant

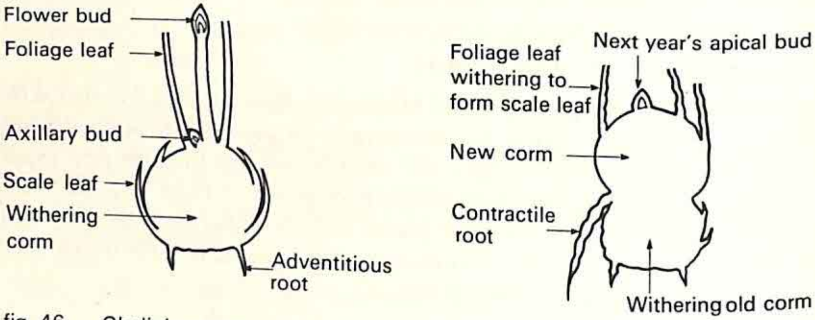
c Formation of new bulb

fig. 45 Onion bulb

Corms Compressed erect underground *stem* with short internodes, bearing leaf scars and axillary buds. Covered by dry, papery scale leaves. Stores *starch* and *glucose*. Apical bud grows into new plant using stored food. Corm withers as food is used. More food is sent down later to base of stem which swells to form new corm on top of old one. Contractile roots pull new corm down into soil. True corms are rare in the tropics but a typical one is the cultivated gladiolus, grown at fairly high altitudes.

a Corm with scale leaves removed




b L.S. growth of new plant

c L.S. formation of new corm

fig. 46 Gladiolus corm

Rhizomes Horizontal underground *stem* swollen with food – mainly *starch*. Terminal bud grows into new plant using stored food. Old leaf bases form circular leaf scars around rhizome. New plant sends food down and lateral bud grows to form new rhizome. Contractile roots keep it underground. Old rhizome does not die away, but lasts for several years. Examples: Canna, ginger, grass.

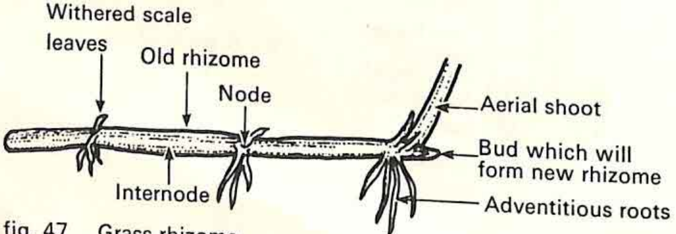
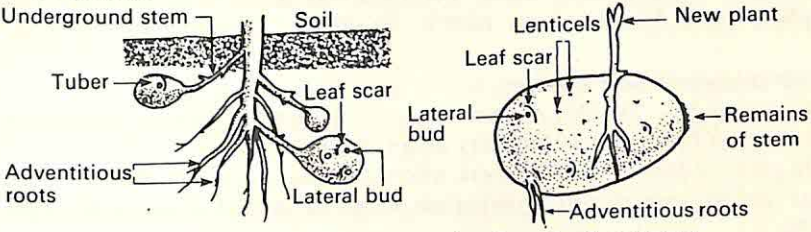


fig. 47 Grass rhizome

Stem tubers Tips of underground *stems* swollen with *starch*. Each axillary bud can form a new plant next year using stored food. Old tubers shrivel and wither. New plant sends food down to ends of underground stems which swell to form new tubers. Examples: Potato and sweet potato.



a Underground stem

b Growth of new plant

fig. 48 Potato plant with tubers

Root tubers Tops of adventitious *roots* swollen with *starch*. Used for growth of leaves and flower each year. Later a fresh supply of food is sent down to new roots which swell to form new tubers. Examples: cassava, cultivated dahlia.

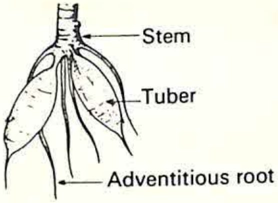
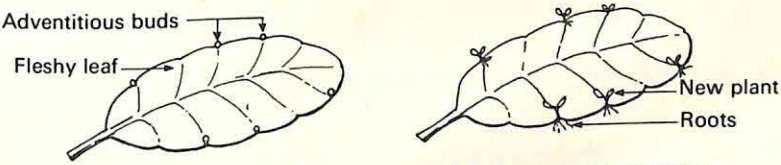


fig. 49 Root tubers of Cassava

Other types of vegetative reproduction which do not involve food storage are:

Adventitious buds *Buds* on the margins of the leaves develop into small plants. These are nourished by the fleshy leaves until they can establish themselves. The leaves drop off the parent plant and the new plants grow into the soil. Examples: Begonia and life plant (Bryophyllum).



a Leaf bearing buds

b New plants developing

fig. 50 Adventitious buds of Begonia

Runners Creeping *stems* above the soil, horizontal to surface. Terminal bud of each stem produces a new plant some distance from the parent. Adventitious roots develop and once established, the runner from the parent shrivels. Examples: Sweet potato, many grasses.

Suckers Underground *stems*. Terminal bud turns up to produce new plant some distance from parent. Examples: Bamboo and banana.

Advantages of food storage

In *mammals* – enables animal to perform exercise without constantly taking in food. Stored fat acts as an insulating layer.
In *plants* – enables rapid growth when conditions suitable. This gives an advantage over slower growing plants which would compete for light etc.

6 Respiration

Respiration is the oxidation of food substances to release energy. The usual food substances are *carbohydrates* and the waste products are *carbon dioxide* and *water*.

Equation:

Glucose + oxygen ⟶ energy + carbon dioxide + water

$C_6H_{12}O_6 + 6O_2 \longrightarrow \text{energy} + 6CO_2 + 6H_2O$

Experiments to demonstrate respiration

Usually easiest to show that carbon dioxide is given out, or in some cases that heat is produced.

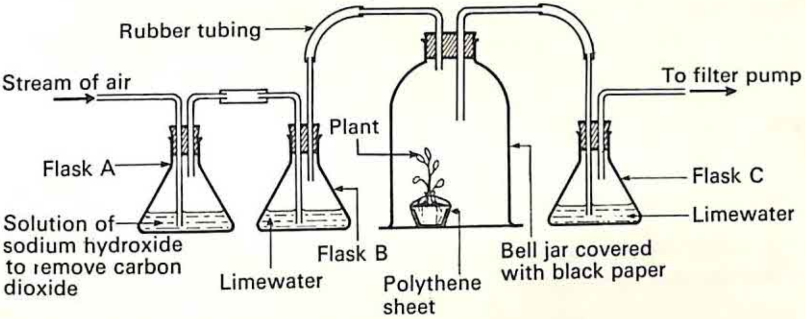


fig. 51 Experiment to show that a green plant gives off carbon dioxide

Experiment: To show that a green plant gives off carbon dioxide

Method: Set up the apparatus shown in the diagram. The bell jar must be covered to prevent photosynthesis taking place. The soil is also covered to prevent escape of any carbon dioxide given off by soil organisms. Turn off the filter pump and draw a stream of air through the apparatus for three hours.

Result: The limewater in flask B remained clear, but that in flask C turned milky.

Conclusion: As carbon dioxide turns limewater milky, and no carbon dioxide was present in the air reaching the plant, the plant must have given off carbon dioxide during respiration.

Experiment: To show that a mammal gives off carbon dioxide
Method: Set up the apparatus in fig. 51 using a mouse instead of a plant and omitting the paper. Turn on the filter pump and draw the stream of air through the apparatus for an hour.

Result: The limewater in flask B remained clear, but it turned milky in flask C.

Conclusion: A mouse gives off carbon dioxide during respiration.

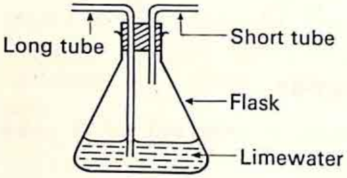


fig. 52 To show that man gives off carbon dioxide

Experiment: To show that man gives off carbon dioxide
Method: Take the apparatus shown in fig. 52. Breathe in twenty times through the short tube so the air bubbles through the limewater first. Observe. Change limewater. Breathe out twenty times down the long tube into the limewater. Observe.

Result: After breathing in the limewater turned very slightly milky. After breathing out it turned completely milky.

Conclusion: Man breathes out more carbon dioxide than he breathes in during respiration.

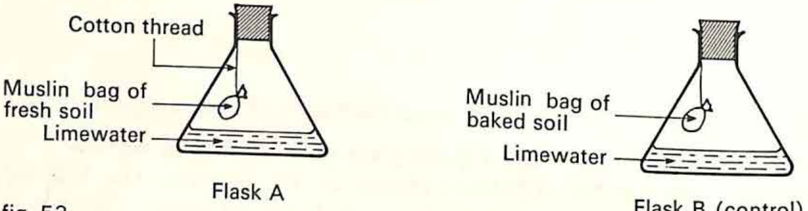
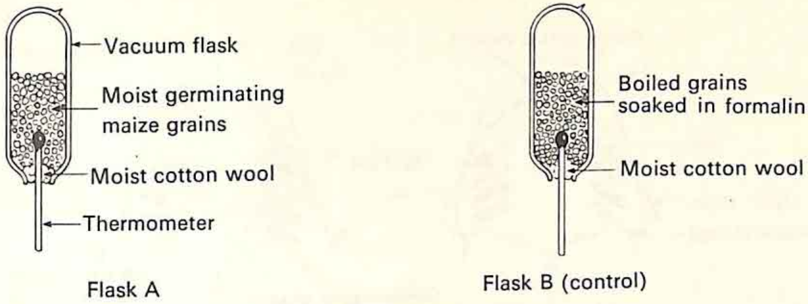


fig. 53

Experiment: To show that micro-organisms give off carbon dioxide
Method: Set up the apparatus shown in fig. 53. Cork both flasks tightly and leave for a day.

Result: The limewater in flask A had turned milky, but that in flask B remained clear.

Conclusion: As the micro-organisms in flask B had been killed, the living micro-organisms in flask A must have given out the carbon dioxide during respiration.


Vacuum flask
Moist germinating maize grains
Moist cotton wool
Thermometer
Boiled grains soaked in formalin
Moist cotton wool

Flask A

Flask B (control)

fig. 5 Experiment to show heat is released

Experiment: To show that heat energy is released by germinating seeds
Method: Set up the apparatus shown in fig. 54, using moist germinating maize grains. Formalin is added to flask B to prevent growth of micro-organisms. Hang the flasks upside down, record both temperatures and leave for two days.

Results: Temperature in flask A was 3°C higher than in flask B.

Conclusion: Heat energy is produced during germination.

Breathing mechanisms in animals

Breathing is the process by which air is taken into, and forced out of, the respiratory organs. Once inside oxygen diffuses into the blood, and carbon dioxide and water vapour diffuse from the blood into the air. This *exchange of gases* is *external respiration*. The actual *oxidation to release energy* is internal or *tissue respiration*.

To be efficient in vertebrates a respiratory surface must have:

a a large surface area;
b a moist surface;
c a good blood supply;
d a thin epithelium separating all the blood vessels from the available oxygen.

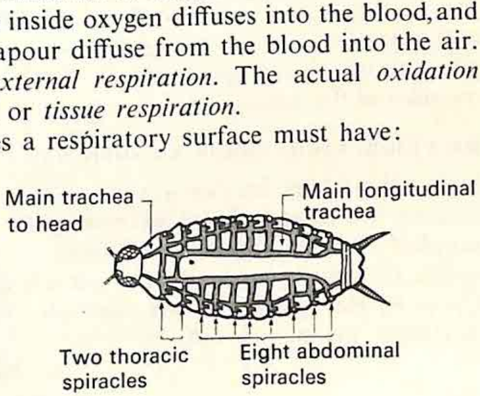
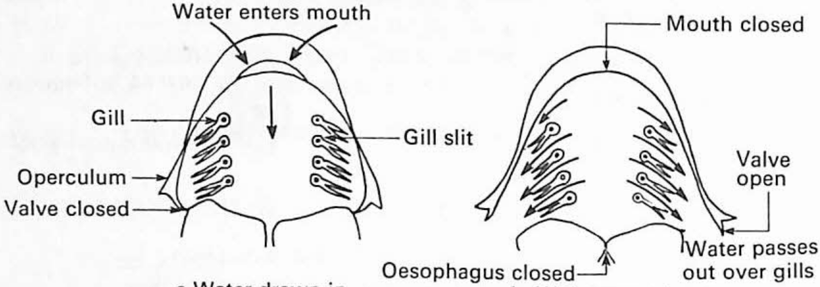


fig. 55 Tracheal system of cockroach

BREATHING MECHANISM OF AN INSECT e.g. cockroach and grasshopper

System of *tracheae* inside the body, opening to the outside by ten pairs of pores called *spiracles*. Tracheae kept open by thickened bands. Spiracles open and close. Exchange of gases helped by movement of body segments. Air passes down tracheal to tracheoles in the body cells where oxygen diffuses in etc. Blood is less important for oxygen distribution than in vertebrates as tracheoles go into the cells.



a Water drawn in
b Water passed out

fig. 56 Breathing mechanism of herring

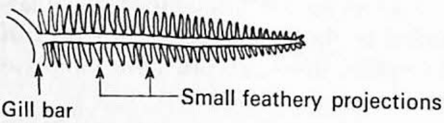


fig. 57 Single gill filament

BREATHING MECHANISM IN A BONY FISH e.g. tarpon (Bulan-bulan), and herring family

Four pairs of gills obtain oxygen from water. Each gill contains many filaments on a gill bar. Large surface area. Well supplied with blood vessels. Epithelium of filaments thin. Covered by an operculum on each side of the head. Water is drawn into the mouth, passed over the gills and out of the operculum by the movements of the floor of the mouth and the operculum.

BREATHING MECHANISM IN AN AMPHIBIAN e.g. the toad and frog

Different mechanisms used at various stages of life cycle. Newly hatched tadpole has three pairs of external gills. Thin-walled, feathery, well supplied with blood vessels. Replaced by internal gills in two to three weeks. Covered by operculum which is fused to body wall in right side. Opens by the spiracle on left side only. Water drawn in and expelled in similar manner to fish.

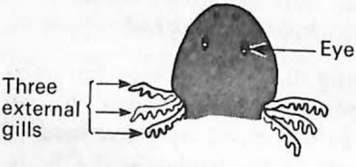
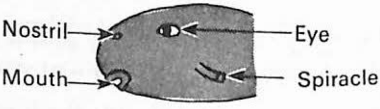


fig. 58 Head of newly hatched tadpole

a From left side



b From right side

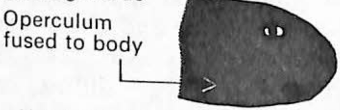


fig. 59 Head of two month old tadpole

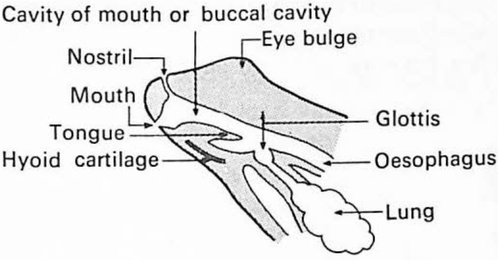


fig. 60 L.S. anterior region of frog to show breathing mechanism

Adult has three breathing mechanisms.

i Skin breathing Skin is moist, thin and well supplied with blood vessels. Oxygen from the air dissolves in the moisture and diffuses through into the blood. Carbon dioxide diffuses out the other way. Used all the time but most value when hibernating at the bottom of the pond.

ii Mouth breathing Mouth remains closed. Nostrils open, floor of mouth drops and air is drawn into the buccal cavity. Gaseous exchange takes place through moist thin lining of mouth. Floor of mouth rises and air is forced out.

iii Lung breathing Mouth remains closed. Occurs about once to every five mouth breaths when the frog is active. Nostrils open, floor of mouth drops and air is drawn in as before. Then nostrils close and floor of mouth rises forcing air down into the lungs where gaseous exchange takes place. Air is expelled by natural elasticity of lungs and pressure from other organs when nostrils open.

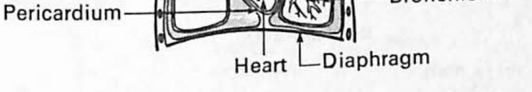


fig. 61 Diagram of the structure and position of the lungs in man

BREATHING MECHANISM IN A MAMMAL e.g. man

Air is breathed through the *nose* where it is filtered, warmed and moistened. It passes to the back of the throat into the voice box or *larynx* and down the *trachea*. The *epiglottis* is a flap which closes when swallowing, so preventing food from entering the trachea which is kept open by incomplete cartilage rings. From the trachea a *bronchus* leads to each lung where it divides into numerous *bronchioles* each ending in a mass of thin-walled *air-sacs* or *alveoli*. Each alveolus is thin-walled and covered with a network of blood capillaries.

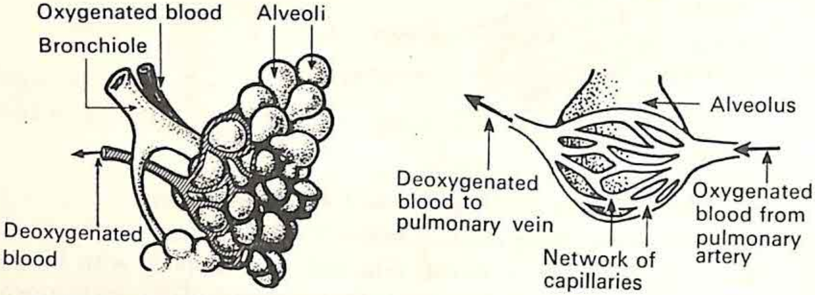
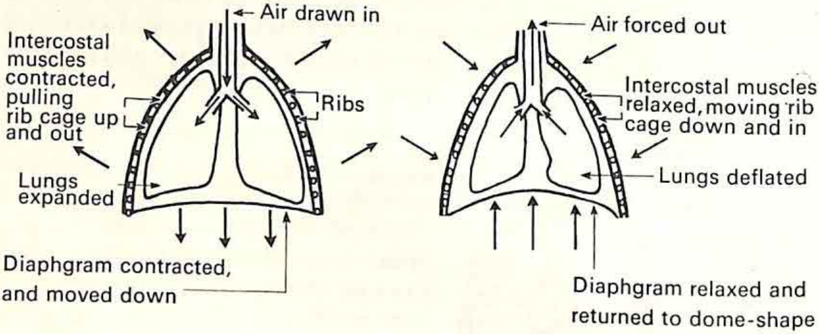


fig. 62 (a) Microscopic structure of the lungs (b) Single alveolus

Breathing movements are brought about by the *diaphragm* and the intercostal muscles between the ribs.

For *inspiration:* volume of thorax is enlarged, so pressure inside decreases and air is drawn in to make pressure equal to atmospheric pressure

For *expiration:* volume is decreased, so pressure inside increases and air is forced out.


Air drawn in
Intercostal muscles contracted, pulling rib cage up and out
Ribs
Lungs expanded
Diaphgram contracted, and moved down
Air forced out
Intercostal muscles relaxed, moving rib cage down and in
Lungs deflated
Diaphgram relaxed and returned to dome-shape

a Inspiration

b Expiration

fig. 63 Breathing mechanism in man

Differences between inspired and expired air

Inspired air		Expired air
Volume composition	Nitrogen 78% Oxygen 21% Carbon dioxide ·04%	Nitrogen 78% Oxygen 14 to 16% Carbon dioxide 4 to 6%
Slightly moist Temperature of surrounding air		Saturated Temperature of body

7 Excretion

Excretion is the removal of waste products of metabolism. If they were allowed to accumulate in solution they would affect the normal chemical reactions. Some are poisonous.

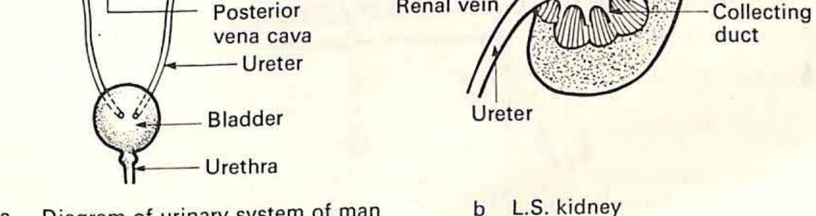
Excretion in animals

AMOEBA

Waste *carbon dioxide* from respiration and waste *nitrogenous substances* such as urea and ammonia from protein breakdown, diffuse from the surface of the amoeba into the surrounding water. The large surface area of the amoeba makes this possible. The removal of excess water by the contractile vacuole is *osmo-regulation*, not excretion, as no excretory products have been found in the vacuole.

MAMMAL e.g. man

Excretory organs	Excretory products
Lungs	Carbon dioxide and water vapour from respiration.
Kidneys	Nitrogenous compounds such as urea from protein breakdown, and excess mineral salts in water.
Skin	Excess minerals salts and a little urea in water.



a Diagram of urinary system of man

b L.S. kidney

fig. 64

THE URINARY SYSTEM

The kidneys have an outer *cortex* and an inner *medulla* as shown in fig. 62b. They consist of a branched system of tubules well supplied with blood vessels. Blood is brought to each kidney in a renal artery which breaks up into numerous capillaries supplying the tubules. The blood is filtered and leaves the kidney through the renal vein. The waste filtered from the blood is urine.

Basic volume composition of urine

Water	96%
Urea	2%
Sodium chloride	1%
Other nitrogenous compounds and other mineral salts	1%

The urine passes down the ureter, and each ureter pours its contents into the bladder where it is stored and passed down the urethra to the outside at intervals.

Further functions of the kidney:

1 *Osmo-regulation* Any water needed by the blood to maintain its composition is reabsorbed from the urine before it leaves the kidney. This varies according to the amount lost in sweat.

2 *Regulation of blood sugar content* Any glucose needed by the blood is reabsorbed in the same way.

3 *Regulation of blood salt content* Any mineral salts needed are also reabsorbed.

THE SKIN

The skin has many functions, the most important being:

a Excretion;
b Regulation of body temperature;
c Sensory function.

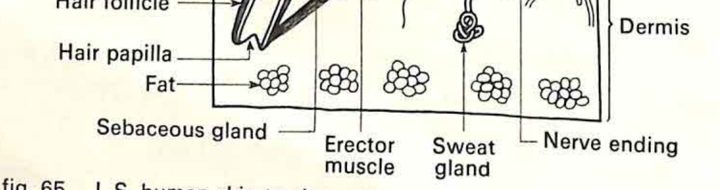


fig. 65 L.S. human skin to show structure

a *Excretion by the skin* takes place through the *sweat glands.* Waste water, mineral salts and a little urea pass from the blood into the sweat glands. The sweat then passes up the ducts and out of the pores onto the surface of the skin where it evaporates.

b *Regulation of body temperature* is carried out in several ways:
i *By the evaporation of sweat* As latent heat is taken from the body to evaporate sweat, the body sweats more when it is overheated in an attempt to lose more sweat. When the body is cold, sweat production decreases.

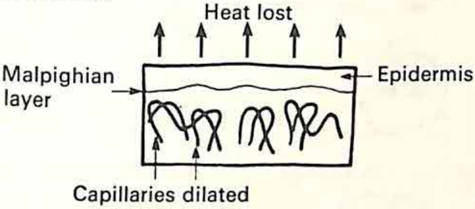


fig. 66 Vasodilation

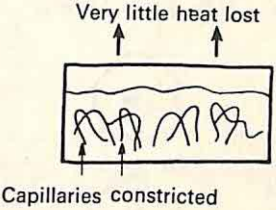


fig. 67 Vasoconstriction

ii *By vasomotor mechanisms*:
Vasodilation is the widening of the blood capillaries under the skin. This occurs when the body is overheated. More blood flows near the surface, so more heat is lost by radiation, conduction and convection.
Vasoconstriction is the narrowing of the blood capillaries under the skin. This occurs when the body is too cool. Less blood flows near the surface so less heat is lost.
iii *By shivering* When the body temperature drops, spasmodic contractions of the hair erector muscles takes place, so heat is produced.

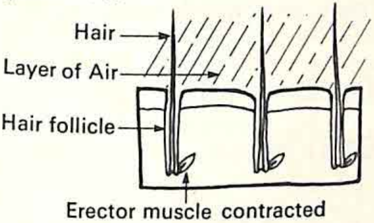


fig. 68 Erection of hairs

iv *By the action of the hairs in furry animals* When the body is too cool, the hair erector muscles contract, making the hairs stand erect, so a layer of air is trapped. This acts as an insulator as air is a bad conductor of heat.
v *Fat beneath the skin* also acts as an insulator.

c *Sensory function* Numerous nerve endings and sense cells in the dermis are sensitive to touch, pressure, temperature and pain.

8 Reproduction

Two main types:

Asexual

Formation of a new organism *without fusion of gametes* e.g. fission, spore formation, budding, vegetative reproduction.

Sexual: Formation of a new organism as the result of the *fusion of two gametes*. This fusion is *fertilization*.

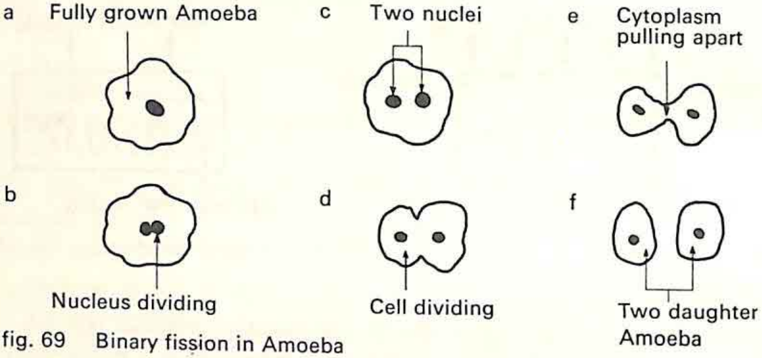


fig. 69 Binary fission in Amoeba

Asexual reproduction

AMOEBA

Binary fission

Amoeba stops moving and withdraws pseudopodia. The nucleus divides into two, then the protoplasm divides to form two daughter amoebae. In unfavourable conditions, a resistant *cyst* is formed. The protoplasm of the Amoeba divides many times inside the cyst, and when conditions are favourable the wall bursts, setting free a large number of daughter amoebae.

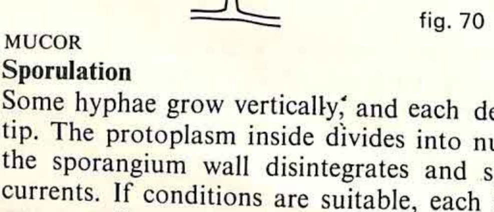


fig. 70 Asexual sporangium of mucor

MUCOR

Sporulation

Some hyphae grow vertically, and each develops a sporangium at its tip. The protoplasm inside divides into numerous spores. When ripe, the sporangium wall disintegrates and spores are dispersed by air currents. If conditions are suitable, each spore germinates to form a new mycelium.

Sexual reproduction and development in animals

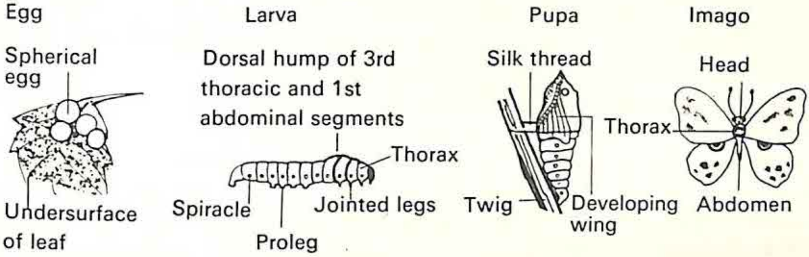


fig. 71 Stages in the life cycle of the Lime Butterfly

INSECTS e.g. the lime butterfly

Fertilization is *internal*. Sperm are passed into the female when male and female genital openings are placed together.

Eggs: Smooth spherical and greenish white. Laid singly on underside of the lime or other citrus plants, showing slight parental care.

Larva: Feeding stage. Dark brown with white markings. Moults three or four times due to growth and changes to a grey-green colour, then to green with grey, black yellow and white markings.
Head with simple eyes, small antennae and biting mouthparts to feed on leaves. Thorax of three segments, each bearing a pair of jointed legs. *Abdomen* of ten segments, bearing pro-legs on segments 3, 4, 5, 6, and 10. Spiracles on each side of thoracic segments 1 and 2 and abdominal segments 1 to 8. Stops feeding and pupates after about three weeks. Spins pad of silk and two threads to attach to support.

Pupa: Stage in which larva is reorganised into an adult. Pale brown, short and fat. After about ten days, cuticle splits and **imago** emerges and spreads crumpled wings to dry and harden.
This change of form is *metamorphosis*. Some insects such as cockroach, locust and grasshopper etc., show *incomplete metamorphosis*, the **egg** hatching to a **nymph** which becomes more like the **adult** with each successive moult.

BONY FISH e.g. tarpon (Bulan-Bulan), and herring family

Males and females collect in shoals in shallow water during the breeding season. Each female lays millions of eggs which the male fertilizes *externally* by passing sperm on to them. No parental care, although some other fish build nests or carry their young. Very large numbers of eggs produced to compensate for lack of parental care. Young fish hatch in two or three weeks and feed on yolk from their yolk sac at first.

AMPHIBIANS e.g. toad and frog

In the breeding season toads and frogs take to water, the smaller male being carried on the female's back, gripping with the aid of horny black pads on his thumbs. As the female lays her eggs the male immediately sheds sperm over them and they are fertilised *externally*. The jelly around each egg swells and they stick together to form spawn masses. Toad spawn is laid in strings. The jelly gives buoyancy, and protection. After about ten days a tadpole hatches from each fertilized egg and feeds on the remains of the yolk. In two or three days its mouth opens and it scrapes microscopic water plants for food. Life cycle illustrated in fig. 72.

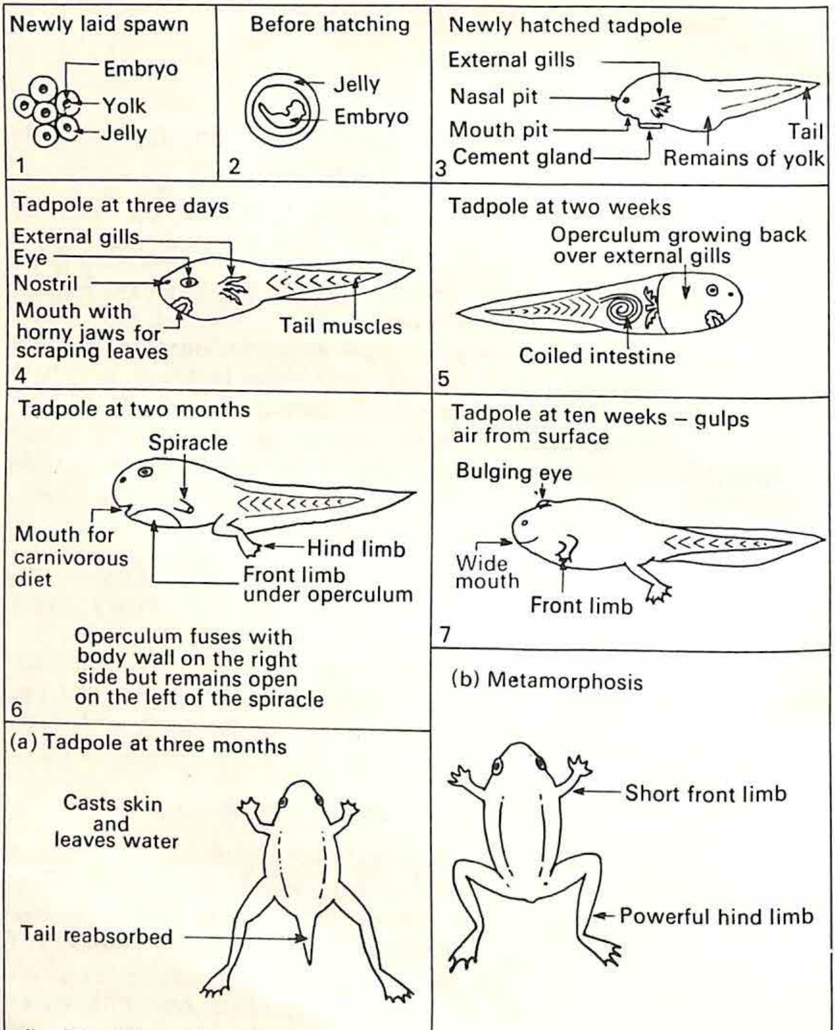


fig. 72 Life cycle and metamorphosis of a toad

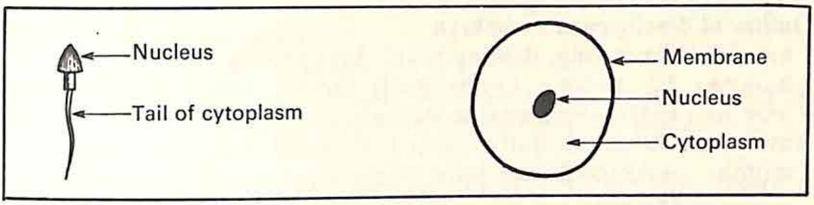


fig. 73 Sperm and ovum of a mammal

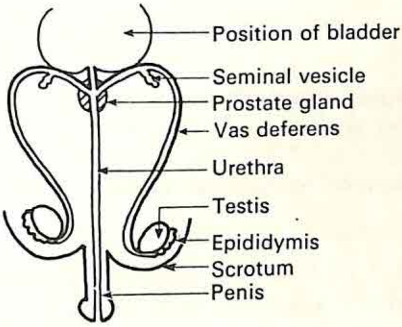


fig. 74 Human male reproductive organs – front view

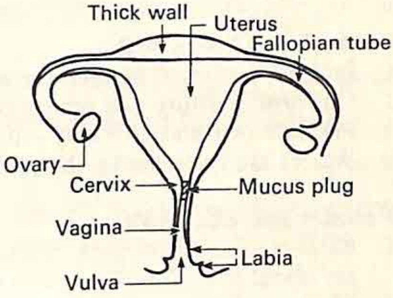


fig. 75 Human female reproductive organs – front view

MAMMALS e.g. man

Spermatozoa made in the *testes* pass into the *epididymis* on each side and up the *vas deferens* to the *urethra*. Secretions from the two *seminal vesicles* and *prostate gland* dilute and activate the sperm which travel in the fluid *semen*. During copulation the erect *penis* is introduced into the female *vagina*; the sperm are ejaculated and they swim up into the *uterus* and *fallopian tubes*. *Ova* are made in the *ovaries*, and once a month one ovary releases a ripe ovum into the *fallopian tube*.

Internal fertilization takes place in the fallopian tube when the nucleus of a sperm fuses with the nucleus of the ovum. A membrane forms around the fertilized egg to prevent entry of further sperm. It starts to divide as it continues its journey to the uterus where it implants in the wall. A *placenta* develops at the point of attachment to which the *embryo* is joined by the *umbilical cord*.

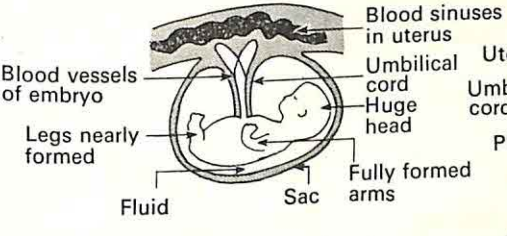


fig. 76 Two month embryo showing blood supply to placenta

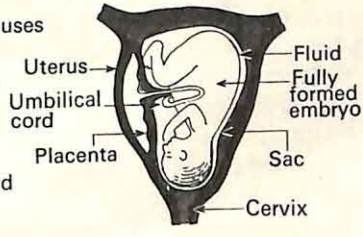


fig. 77 Nine month embryo in uterus

Outline of development of embryo

1 month	5 mm long. Beating heart. Arm and leg buds.
2 months	2·5 cm long. Limbs nearly formed. Large squarish head.
4 months	External sex organs formed.
5 months	Outwardly fully formed. Covered with soft down.
7 months	Average 35 cm long. Weight 1·4 kg. Fully formed. No body fat.
9 months	Average 50 cm long. Weight 3·2 kg. Body fat deposited. Birth.

Parental care before birth

1 Embryo protected by membranes and liquid of uterus;
2 Uniform moisture and temperature ensures uniform growth;
3 Placenta provides constant supply of soluble foods and oxygen;
4 Wastes are removed by the placenta to be excreted by the mother.

Parental care after birth

1 Baby is suckled on milk produced by mother's mammary glands for about 6 months. Later mother provides more solid foods;
2 Mother provides warmth, clothing, protection from danger and disease, companionship and eventually knowledge of how to fend for itself.

Note: The capillaries of the mother's blood run close to those of the embryo in the placenta so any diffusible substances can be interchanged. The blood does not mix.

Birth is brought about by contractions of the muscles of the uterus which gradually become stronger and push the baby head first down the vagina. The umbilical cord is cut and the baby begins to breathe with lungs.

BIRDS e.g. domestic fowl

Sex organs enlarge during the breeding season. Male cock fowl mounts hen and passes sperm into her when the genital openings are placed together. Eggs are fertilized *internally*. Yolk and albumen are deposited around each egg and it is covered by a membrane and a shell, and laid about 24 hours after fertilization.

Yolk provides food.

Albumen provides food and water.

Chalazae twist the yolk so the embryo always lies on top nearest the warmth of the hen.

Shell and *membrane* are porous; allowing diffusion of oxygen into, and carbon dioxide from, the air space.

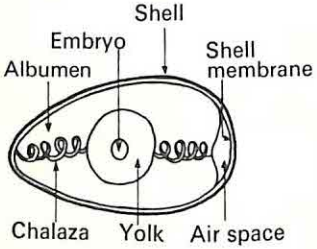


fig. 78 Diagram of internal structure of bird's egg

Parental care is shown by:

a Building a nest for the eggs;

b *Incubation* until they hatch (21 days in domestic fowl) and keeping them warm, and eventually teaching them to fend for themselves.

Sexual reproduction and development in flowering plants

FLOWER STRUCTURE

The flower is the *reproductive structure*. It is generally composed of the following parts:

Receptacle – expanded end of flower stalk which bears the floral parts.

Calyx – consists of *sepals*. Usually green. Protects flower in bud.

Corolla – consists of *petals*. Often coloured, or scented to attract insects.

Androecium – male part of flower. Consists of *stamens*. Each stamen consists of a *filament* bearing an *anther* containing four *pollen sacs*. Produces pollen grains which contain the *male gametes*.

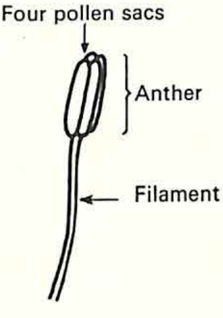


fig. 79 Typical stamen

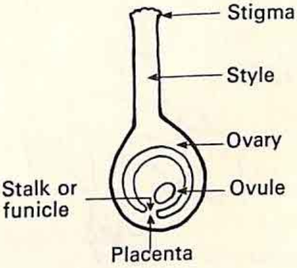


fig. 80 L. S. typical carpel

Gynaecium – female part of flower. Consists of one or more *carpels* each containing one or more *ovules* in an *ovary*. A *style* bearing a stigma extends from the ovary. Ovary contains the *female gametes* which when fertilized become seeds.

Pollination mechanisms

The transfer of pollen from the anthers to the stigma is pollination.

Self pollination is the transfer of pollen from the anthers to the stigma of the *same* flower.

Cross pollination is the transfer of pollen from the anthers of one flower to the stigma of *another*.
Insects and *wind* are the main pollinating agents.

General characteristics of insect-pollinated flowers

a Brightly coloured petals;
b Large or grouped in large heads;
c Scent;
d Nectar;
e Often shaped to allow insect to land or to enable the stigma to touch it first ;
f Heavy, sticky pollen;
g Stigmas broad and often grooved.

General characteristics of wind-pollinated flowers

a Petals and sepals usually green, small or absent;
b Small size;
c No scent;
d No nectar;
e Often arranged for shaking out pollen e.g. catkins and hanging anthers;
f Pollen light and powdery;
g Stigma feathery with long styles.

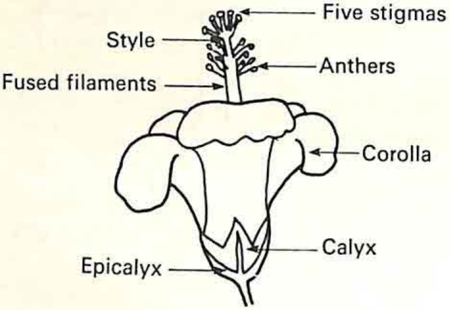


fig. 81 Hibiscus flower

STRUCTURE OF HIBISCUS

Large, brightly coloured.

Calyx: 5 fused green *sepals. Epicalyx* of 5 parts present outside calyx.

Corolla: 5 large, free *petals,* usually red, pink or orange.

Androecium: Numerous *stamens*. Red *filaments* fused to form a protruding tube.

Gynaecium: 5 *carpels* with *ovaries* and *styles* fused together. 5 free *stigmas.*

Pollination: Insects

Fruit: Capsule, splitting into 5 parts.

STRUCTURE AND POLLINATION OF FLOWERS IN THE BEAN FAMILY

Runner-bean, broad bean, pea, cassia, acacia and mimosa etc. all have similar floral structure. Flowers irregular.

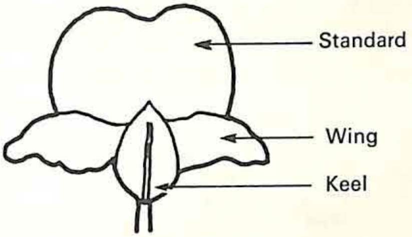


fig. 82 Bean flower

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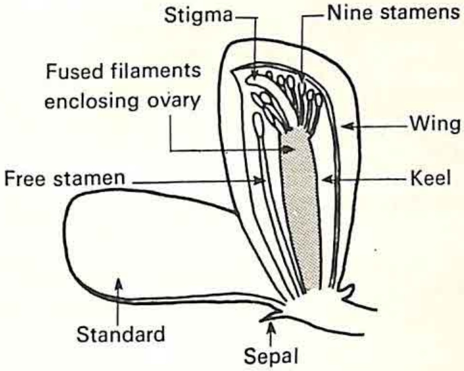


fig. 83 Structure of bean flower

Calyx: 5 small green *sepals* fused to form a tube.

Corolla: 5 unequal *petals*. One large standard, two wings and two keel petals fused. Various colours e.g. mimosa-pink, cassia-yellow, runner bean-red.

Androecium: 10 *stamens. Filaments* of 9 joined to form a tube, one free. Enclosed in keel petals.

Gynaecium: *Carpel* of one ovary containing several ovules, in a row. Long flattened shape. *Style* long, *stigma* sticky.

Pollination: Insects. Heavy insect lands on wing petals and its weight pushes down the keel so the stigma picks up pollen from its undersurface and stamens brush it with more pollen. Self-pollination can occur otherwise.

Fruit: Legume

STRUCTURE AND POLLINATION OF THE MAIZE FLOWER

No true **petals** or **sepals.** Male and female parts enclosed in *bracts* or *glumes.*

Male flowers: Many in pairs on stalks. 4 glumes surrounding androecium of 3 stamens with long filaments. Anthers swing outside glumes.

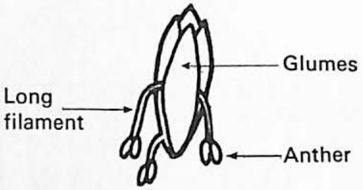


fig. 84 Structure of male maize flower

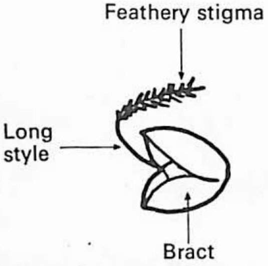


fig. 85 Structure of female maize flower

Female flowers: Many arranged on a *cob*. Each flower is surrounded by bracts. Gynaecium of one carpel containing one ovule. Style long. Stigma feathery, hanging out of the flower.

Pollination: Wind. Male flowers ripen first. Masses of pollen produced, as much is lost.

Fruit: Grains similar to Achenes.

Fertilization

This follows pollination. Time taken varies from less than a day to one year. Pollen grain absorbs food from stigma and puts out a tube which grows down the stigma to the ovary. It enters an ovule through a hole, the *micropyle*, and a male nucleus from the pollen tube fuses with the female nucleus of the ovule. The ovule develops into a *seed,* and the ovary develops into a *fruit*.

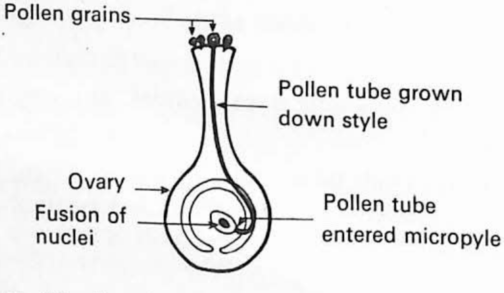


fig. 86 Fertilization

Dispersal by wind

a Pappus of hairs

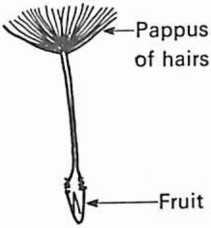


fig. 87 Sunflower fruit

b Winged fruit

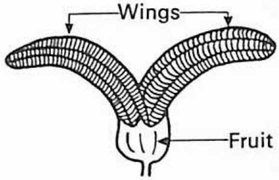


fig. 88 Dipterocarpus fruit (neram)

c Winged seed

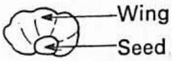


fig. 89 Spathodea seed

d Censer mechanism

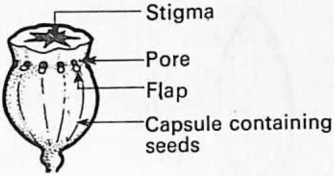


fig. 90 Poppy capsule

Dispersal by animals

a Hooks or stiff hairs

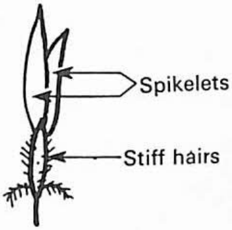


fig. 91 Lovegrass fruit

b Succulent with large seed

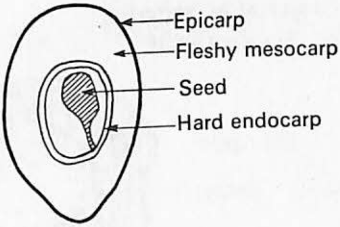


fig. 92 Mango fruit

c Succulent with small indigestible seeds

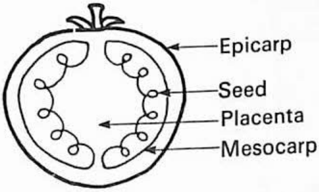
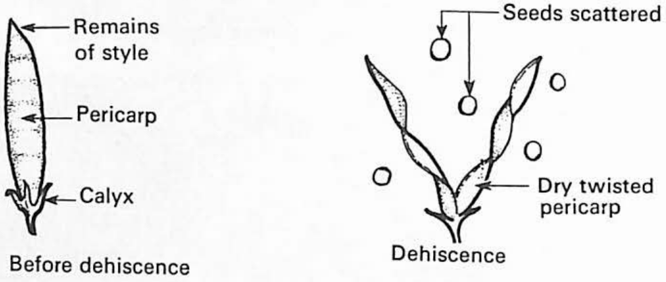


fig. 93 Tomato fruit cut in half

Self dispersal

a Explosion by drying

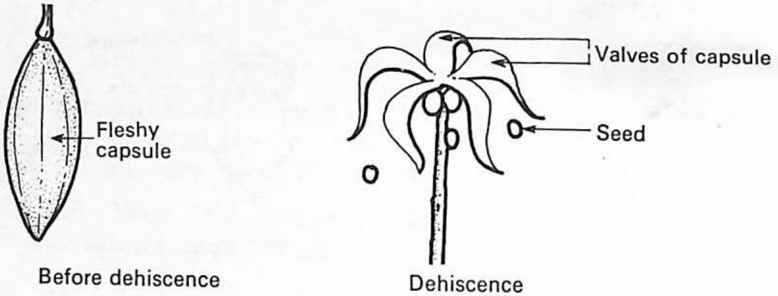


Before dehiscence

Dehiscence

fig. 94 Legume of bean

b Explosion by turgidity



Before dehiscence

Dehiscence

fig. 95 Balsam fruit

Dispersal by water

a Buoyant fruit

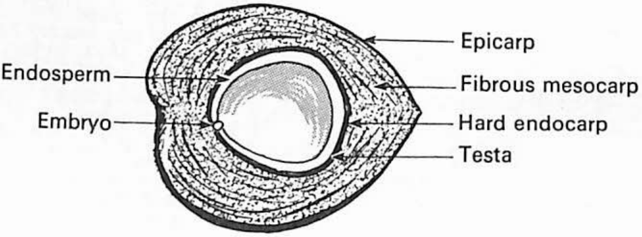


fig. 96 Coconut fruit cut in half

b Buoyant seed

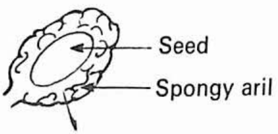


fig. 97 Water-lily seed

COMPARISON OF VEGETATIVE AND SEXUAL METHODS OF REPRODUCTION IN PLANTS

Advantages of vegetative reproduction

1 Quicker
2 Parent plant usually has stores of food available for offspring.
3 No risks during seed production and dispersal.
4 No risks during germination or growth of the young seedling.
5 Offspring have same characteristics as parent. Useful commercially.

Disadvantages of vegetative reproduction

1 Offspring open to competition with each other and the parent.
2 No dispersal so new soil not colonised.
3 If parent plant becomes diseased, this spreads to offspring.

Advantages of sexual reproduction

1 Hybrid vigour due to hereditary material from two parents.
2 Dispersal lessens chance of competition.
3 New soil colonised.
4 Large numbers of seeds, so large number of potential offspring.

Disadvantages of sexual reproduction

1 Slower
2 Risks involved in pollination, seed production, dispersal and germination.

ARTIFICIAL PROPAGATION

Artificial methods of vegetative reproduction are used in agriculture and horticulture. Examples:

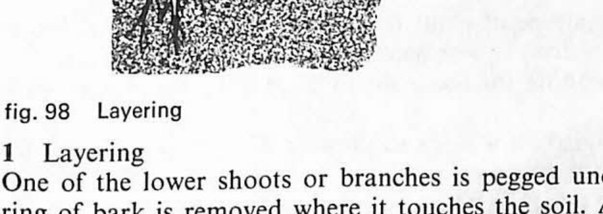


fig. 98 Layering

1 Layering
One of the lower shoots or branches is pegged under the soil and a ring of bark is removed where it touches the soil. Adventitious roots develop after a few months and the branch is then cut off from the parent and left to grow independently. Performed with bougainvillea, lemon, etc.

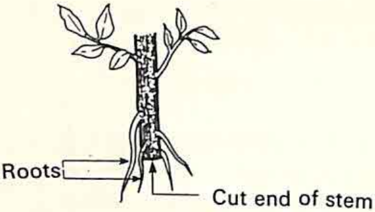


fig. 99 Cutting forming roots

2 Stem cuttings

The top part of a stem bearing an axillary bud or lateral shoot is cut off just below a node and placed in the soil. Adventitious roots grow from the node. The cut end is often dipped in a solution of auxin to encourage root growth. Performed with rose, hibiscus, sugar cane, etc.

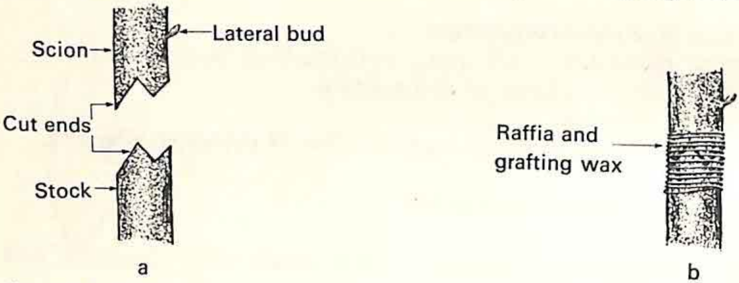


fig. 100 Grafting

3 Grafting

A small branch or bud bearing exposed *cambium* is the *scion*. This is inserted into a specially shaped incision exposing the cambium in the *stock* which has a well established root system. The two are bound together and often sealed with *grafting wax* to prevent infection or drying out. The cambia grow so that the scion becomes firmly attached to the stock but retains its individuality. Various different types of grafting are performed with mango, pomelo, plum, peach, apple, etc.

ADVANTAGES OF ARTIFICIAL PROPAGATION

1. Exactly the same type of plant is produced each year so the same type of flower or fruit can be guaranteed for market purposes.
2. Quicker than waiting for the plant to develop to the reproductive phase.
3. Grafting often enables a plant to grow in a soil which would not be suitable if it had to root itself.
4. Young healthy plants can be grafted onto ones which are bearing poor or unsuitable fruit or flowers.
5. Some plants such as bananas, pineapples and other seedless fruits can only be propagated artifically.

9 Growth

Growth is an increase in size of an organism by the manufacture of new protoplasm. It can be measured by increase in volume, weight, area, height or width. Growth is accompanied by internal changes or development, which leads to an increase in complexity. Animals and plants differ in their methods of growth as stated on page 3.

Growth in green plants

Growth in *length* occurs in actively dividing regions called *meristems* just behind the root and shoot tips.

Experiment: To find the region of growth in the radicles of broad bean seedlings

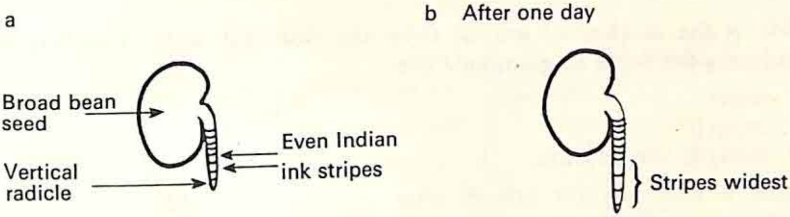


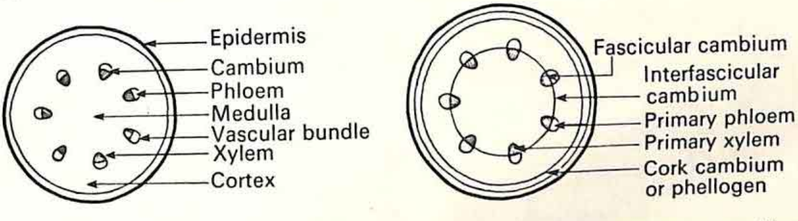
fig. 101 To find growth region in broad bean radicle

Method: Germinate 10 broad bean seeds and turn them so their radicles grow vertically. Mark the radicles evenly with Indian ink stripes as shown in fig. 101a. Leave them pinned to cork on moist blotting paper for a day.

Result: The stripes were wider just behind the tip as shown in fig. 101b.

Conclusion: The growing region of a radicle is just behind the tip.

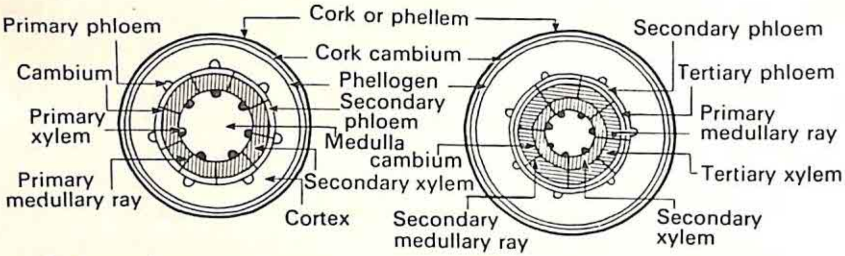
Growth in *girth* occurs in *secondary meristems* or *cambia* which divide later in life. This is secondary thickening.



a T. S. young stem

b Formation of interfascicular cambium

fig. 102 a and b Secondary thickening in sunflower stem



c 1st year of secondary growth d 2nd year of secondary growth

fig. 102 c and b

Much growth in plants causes a *change of form* e.g. new flowers or leaves etc. develop. This is illustrated by *germination*.

Germination

This is the *renewal of growth* from the dormant stage. Conditions necessary for seeds to germinate are:

i water;
ii oxygen;
iii suitable temperature.

Light is necessary for growth after germination. Plants deprived of light become *etiolated*.

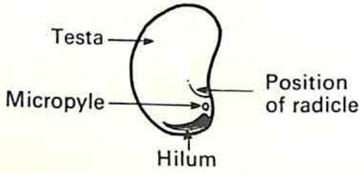


fig. 103 Broad bean seed

Structure and germination of the broad bean seed

Dicotyledon having *two* cotyledons. Covered by *testa*. Water enters through *micropyle*. *Hilum* is the scar where the seed was attached to the fruit. *Embryo* obtains food from store in cotyledons. Enzymes digest it. *Hypogeal* germination – cotyledons remain beneath soil.

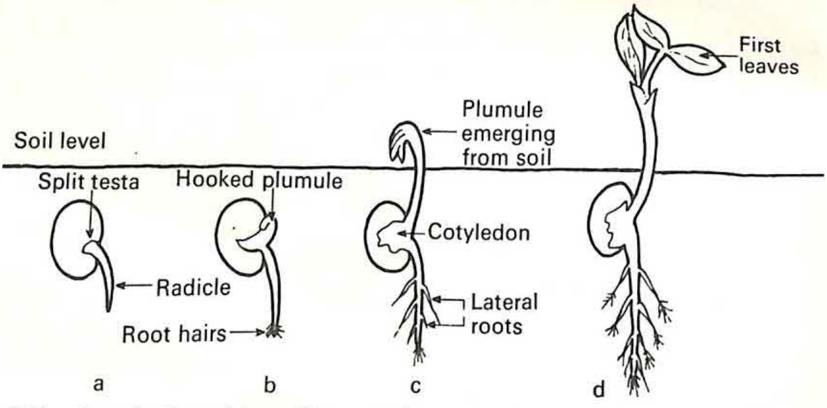


fig. 104 Germination of broad bean seed

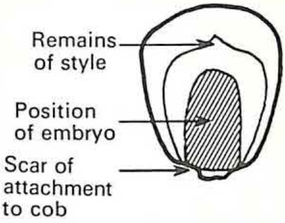


fig. 105 Maize seed

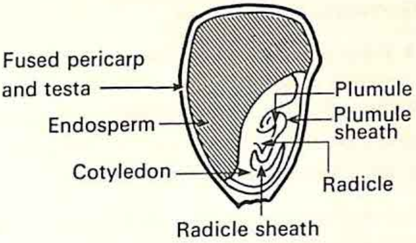


fig. 106 L. S. maize seed to show structure

Structure and germination of the maize seed

Monocotyledon having *one* cotyledon. Food stored in *endosperm*. Cotyledon sends enzyme to digest stored food to be used by embryo. Testa fused to fruit coat or *pericarp*. *Hypogeal* germination.

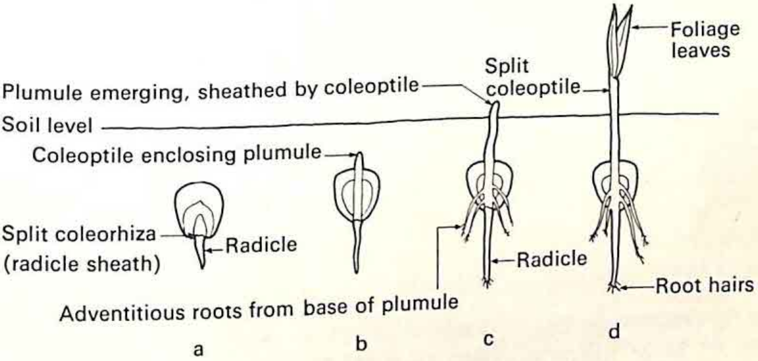

Foliage leaves
Split coleoptile
Plumule emerging, sheathed by coleoptile
Soil level
Coleoptile enclosing plumule
Split coleorhiza (radicle sheath)
Radicle
Radicle
Root hairs
Adventitious roots from base of plumule
a
b
c
d

fig. 107 Germination of maize seed

In *epigeal* germination, the cotyledons come above soil and photosynthesise until the new shoot is established. e.g. sunflower and castor oil seeds.

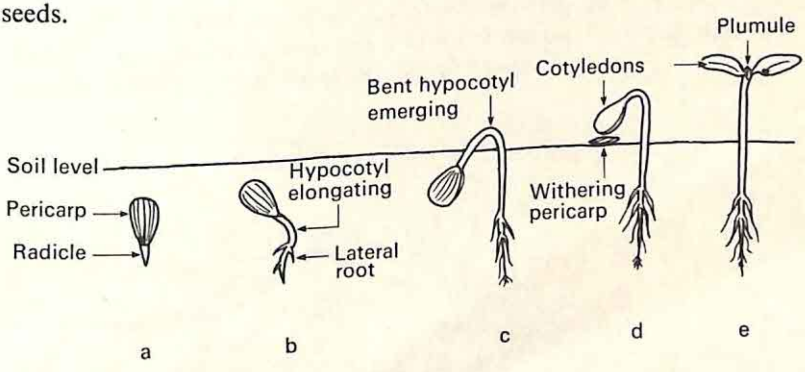


fig. 108 Germination of sunflower seed

Growth in animals

Animals such as Amoeba make new protoplasm and produce a general increase in size.
Cells of more complicated animals similarly increase in size, but cell division also takes place in young animals producing larger numbers of cells which then increase in size.

Change of form is seen in animals such as insects, frogs and toads which undergo *metamorphosis* as described on pages 49 and 50.

10 Locomotion

Locomotion is the movement of a whole organism from place to place. Characteristic of *animals.* Most plants can only perform movement due to growth or turgor changes etc.

LOCOMOTION IN AMOEBA: AMOEBOID MOVEMENT

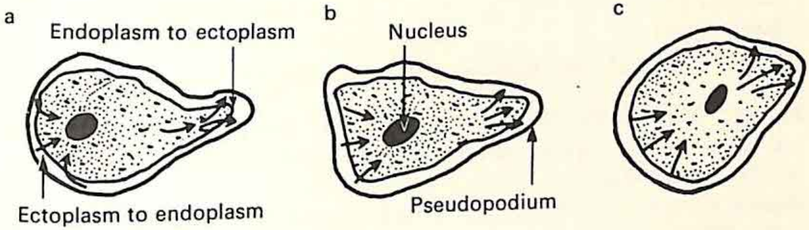


fig. 109 Locomotion in amoeba

Amoeba moves over mud or other solid surfaces by putting out *pseudopodia.* The fluid *endoplasm* changes to the more solid *ectoplasm* at the tip, then flows back to the rear end and is changed to endoplasm which streams forward and repeats the process. Not very effective in water when not near a solid surface.

LOCOMOTION IN INSECTS e.g. cockroach and grasshopper

Locomotion by walking or flying, brought about by muscles attached to the *exoskeleton* which is made of *chitin,* and is jointed to permit movement.

Walking Three pairs of jointed legs attached to thorax. Each leg moved by pairs of antagonistic muscles joined to exoskeleton. One bends or flexes the joint and the other straightens or extends it. Legs move in threes. Leg 1 and 3 on one side and leg 2 on the opposite side move forward together, then the second three are moved.

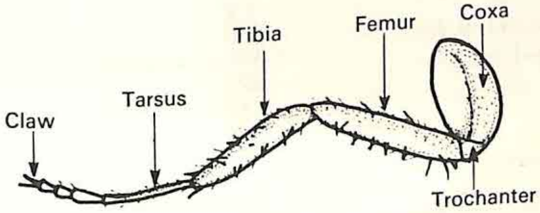


fig. 110 Leg of cockroach

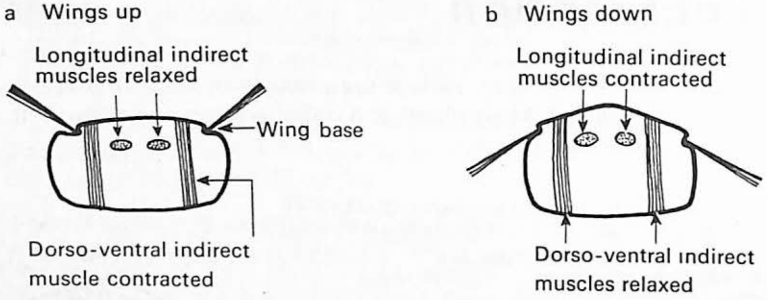

a Wings up
Longitudinal indirect muscles relaxed
Wing base
Dorso-ventral indirect muscle contracted
b Wings down
Longitudinal indirect muscles contracted
Dorso-ventral indirect muscles relaxed

fig. 111 T. S. cockroach to show attachment of flight muscles

Flying Two pairs of wings attached to thorax. Moved by three sets of muscles: direct, indirect and accessory indirect. All attached to the exoskeleton.

Action shown in fig. 111. Each wing is turned on its axis in a figure of eight. When raised it moves upwards and backwards, and when lowered it moves downwards and forwards to drive the insect forwards and upwards.

The grasshopper can leap or fly. It leaps by using its elongated hind limbs to give extra leverage.

LOCOMOTION IN A BIRD

Most can walk with their legs or fly with their wings. Flying is most characteristic.

Adaptation to flight

1 Lightness due to hollow bones;
2 Streamlined body;
3 Efficient 'double' breathing system;
4 One pair of wings covered with feathers, giving large surface area;
5 Very large powerful pectoral muscles to move the wings;
6 Rigid endoskeleton for muscle attachment;
7 Deep extension of sternum for attachment of pectoral muscles.

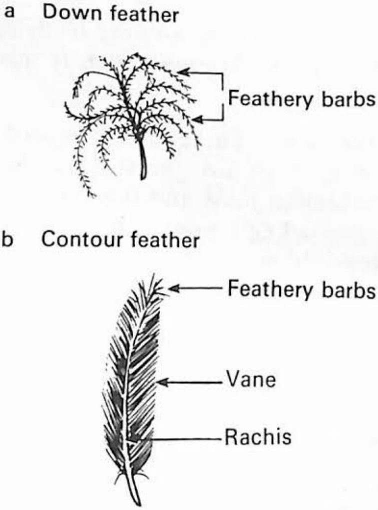


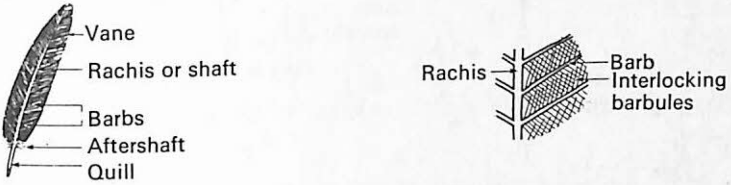
fig. 112 Types of feather

Feathers

Down feathers trap air close to the body for insulation – more common in baby birds.

Contour or *covert* feathers provide further insulation and also help in flight.

Quill or *flight* feathers provide a large area of resistance to air for flight. Barbules interlocked for this purpose as shown in fig. 112 d and e.


c Quill feather

d Barbs of quill feather magnified

e Barbs magnified further

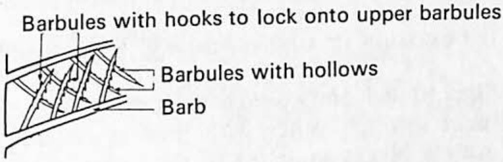


fig. 112 Types of feather

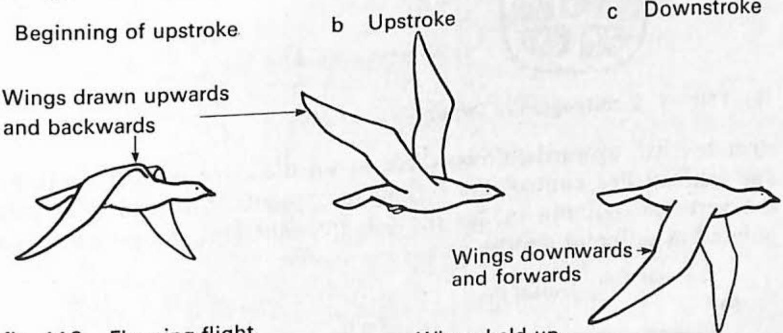
Types of flight

a *Flapping*:

b *Gliding*: Wings and tail outspread. Maintains forward movement but gradually loses height.

c *Soaring*: Wings and tail outspread as for gliding, but upward lift produced by air currents.

In all forms of flight, tail feathers (quills) are used to steer and to help landing.


a Beginning of upstroke

b Upstroke

c Downstroke

Wings drawn upwards and backwards
Wings downwards and forwards

fig. 113 Flapping flight

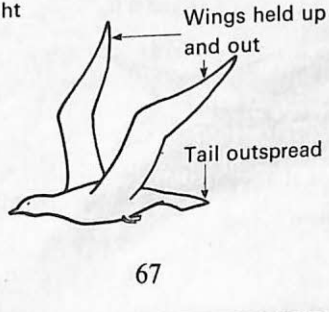

Wings held up and out
Tail outspread

fig. 114 Gliding flight

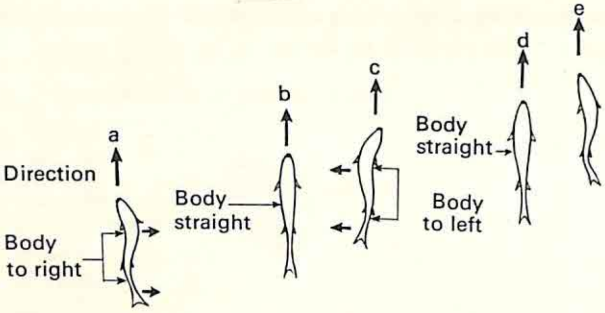


fig. 115 Swimming movements of herring family

LOCOMOTION IN A BONY FISH e.g. Tarpon and herring family

Streamlined body and backwardly pointing scales allow rapid movement through water with little resistance. Propelled by antagonistic muscle blocks attached to the vertebral column on either side of the body. Vertebral column is flexible but incompressible and is part of the endoskeleton.

Muscle blocks on one side contract and those on the other side relax alternately. Tail fin helps forward thrust. Pectoral and pelvic fins steer the fish upwards, downwards or on the same level. Dorsal, anal and ventral fins control the rolling movements. Swim bladder below the vertebral column makes the fish buoyant and the pressure is regulated at different depths.

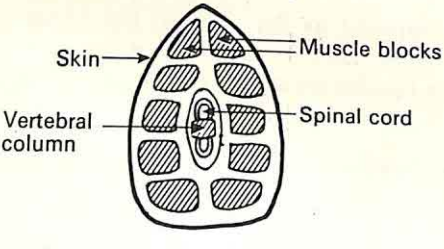


fig. 116 T. S. tail region of tarpon

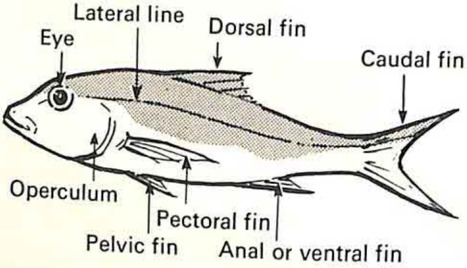


fig. 117 Position of fins

LOCOMOTION IN A MAMMAL e.g. Man

In man, walking, running and jumping are brought about by contraction of antagonistic pairs of muscles attached to the endoskeleton.

Human skeleton
Composed of bone and cartilage.

Axial skeleton: skull, vertebral column, ribs and sternum forming an axis.

Appendicular skeleton: limbs and limb girdles attached to the axis.

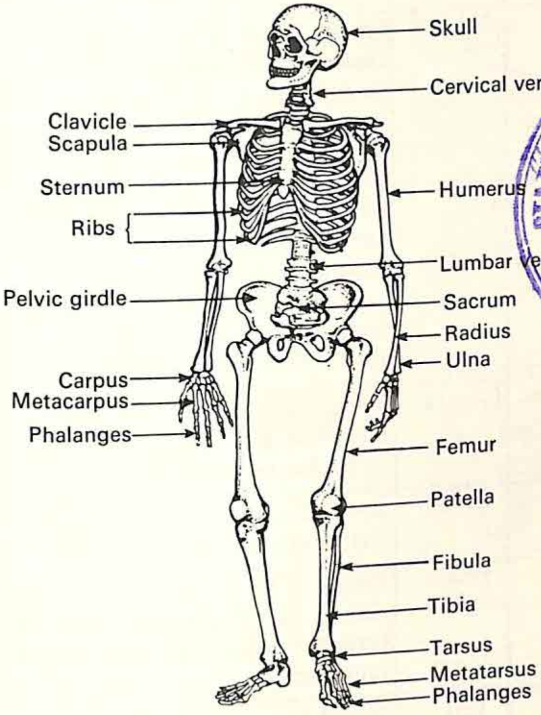


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fig. 118 Skeleton of man

Functions of the skeleton

1 Supports the body and internal organs.
2 Protects certain internal organs e.g. heart, lungs, brain and spinal cord.
3 Maintains body shape.
4 Provides surfaces for muscle attachment to enable movement.
5 Red blood corpuscles are produced in the marrow at the ends of the long bones.

Vertebral column

Composed of 33 small bones called *vertebrae,* each with the following basic structure:

A solid body or *centrum* which supports an arch of bone, the *neural* arch. Between centrum and neural arch is the neural canal through which the spinal cord runs. The neural arch bears a neural spine and transverse processes for muscle attachment. On the transverse processes are smooth surfaces or *facets* for articulation with adjacent vertebrae.

There are five main types of vertebrae:

Type	Number	Region	Adaptations
1 Cervical	7	Neck	Small. Holes in transverse processes for artery to brain. Forked neural spine for ligament to support head.
Specialised: Atlas	1st cervical vertebra		Ring-shaped to support skull. No centrum. Articulates with skull to permit nodding.
Axis	2nd cervical vertebra		Odontoid process projects from anterior end of centrum. Articulates with atlas to allow it to pivot when the head is turned.
2 Thoracic	12	Thorax	Long downwardly pointing neural spines for back muscles. Articulating facets for ribs.
3 Lumbar	5	Loins	Large and strong with extra projections for strong back muscles.
4 Sacral	5	Pelvic	Fused to form sacrum which in turn is fused to pelvic girdle to transmit thrust in running and jumping.
5 Coccygeal	4	Tail	Fused to form coccyx. Reduced structure. Slight movement to help childbirth.

Functions of the vertebral column

1. The *curves* and *discs* of cartilage between the vertebrae give *flexibility.*
2. Absorbs *shock.*
3. Supports *weight* of body.
4. Provides surface for *muscle attachment.*
5. Protects *spinal cord.*

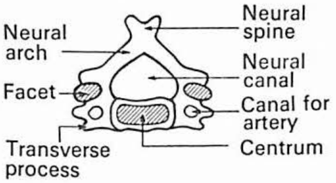


fig. 119 Cervical vertebra – anterior view

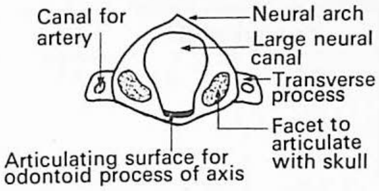

Canal for artery
Neural arch
Large neural canal
Transverse process
Facet to articulate with skull
Articulating surface for odontoid process of axis

fig. 120 Atlas – anterior view

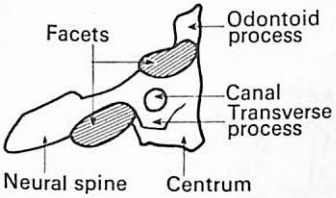


fig. 121 Axis – lateral view

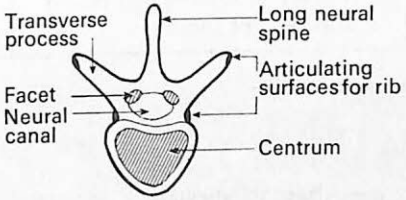


fig. 122 Thoracic vertebra

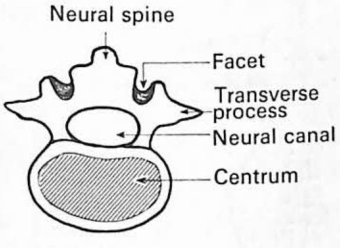


fig. 123 Lumbar vertebra – anterior view

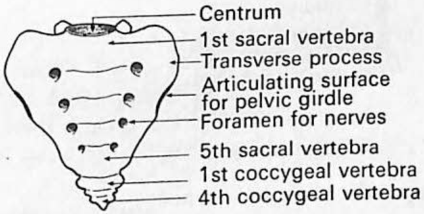
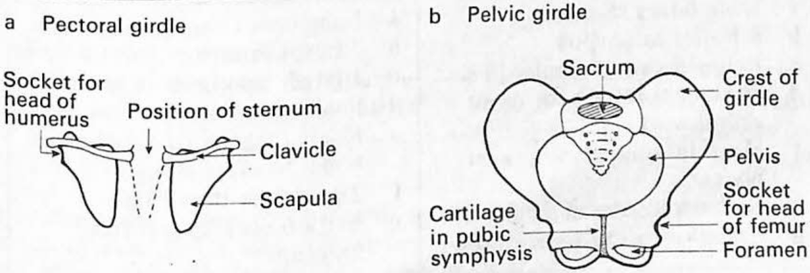


fig. 124 Sacrum and coccyx – ventral view


a Pectoral girdle

b Pelvic girdle

fig. 125 Limb girdles

Comparison of limb girdles

Pectoral girdle	Pelvic girdle
a 4 bones: – 2 shoulder blades or *scapulae*. 2 collar bones or *clavicles*.	**a** 6 fused bones
b Provides surfaces for muscle attachment.	**b** Provides surfaces for muscle attachment.
c Provides articulating surfaces for arms.	**c** Provides articulating surfaces for legs.
d Keeps arms wide apart for reaching and grasping.	**d** Transmits body weight to legs.
e Forms additional protection for back of thorax.	**e** Transmits thrust from legs when running etc.
	f Supports organs of abdomen.
	g Forms birth canal in female.

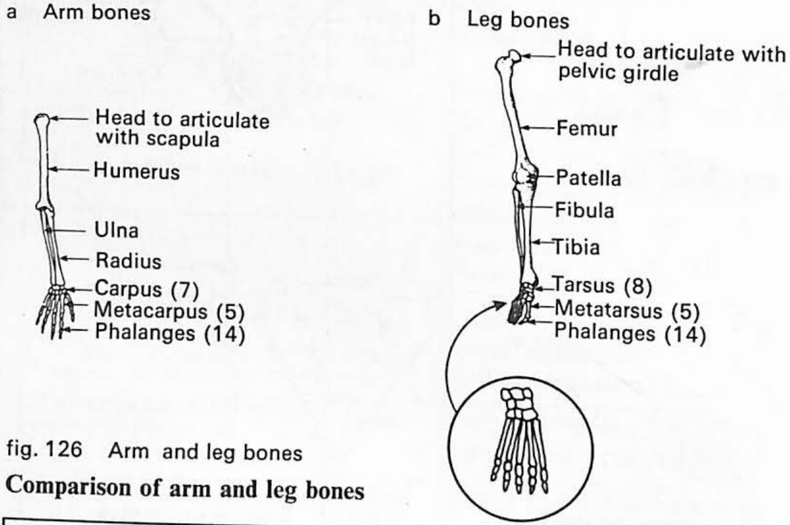


fig. 126 Arm and leg bones

Comparison of arm and leg bones

Arm bones	Leg bones
a Long bones shorter	**a** Long bones longer and thicker.
b 8 bones in carpus	**b** 7 bones in tarsus.
c Bones of carpus similar in size.	**c** 1 larger heel bone in tarsus.
d Phalanges longer for more skilful work.	**d** Phalanges shorter
e Hand in same plane as arm bones.	**e** Foot at right angles to leg bones to support body.
f *Radius* and *ulna* of similar size.	**f** *Tibia* larger than *fibula*
g *Ulna* projects to form elbow.	**g** Extra bone *patella* forms kneecap.

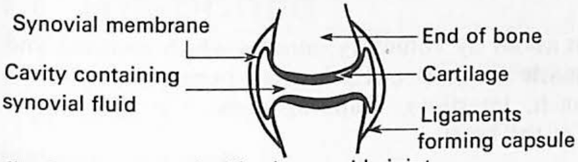


fig. 127 L. S. typical freely movable joint

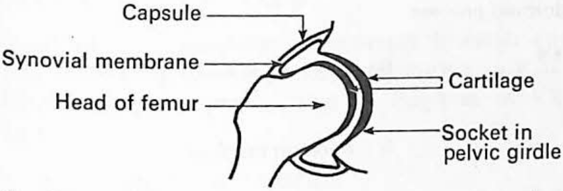


fig. 128 L. S. hip joint

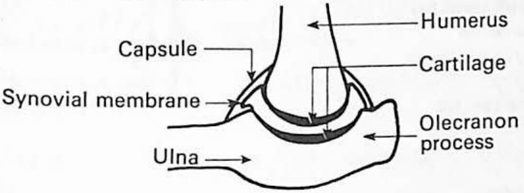


fig. 129 L. S. elbow joint

Joints

A joint is any point where two or more bones of the skeleton meet and articulate. They do not necessarily move. Main types:

1 *Immovable joints* e.g. bones of skull and pelvic girdle.

2 *Slightly movable joints* e.g. between the vertebrae.

3 *Freely movable joints* e.g. all of this type have these characteristics in common:

a Ends of bones covered by *articular cartilage*;

b Ends bound by *capsule of ligaments*;

c Joint cavity filled with lubricating *synovial fluid* secreted by the *synovial membrane.*

Different types of synovial joint

a Ball and socket joint Rounded end of one bone fits into cavity in another bone. Movement possible in all directions e.g. rounded head of femur fits into socket of pelvis, rounded head of humerus fits into socket of scapula.

b Hinge joint Convex surface of one bone fits onto concave surface of another in such a way that movement is possible in one plane only e.g. elbow, knee, phalanges of fingers and toes.

c Pivot joint Allows rotation e.g. where atlas pivots on olecranon process of axis.

Movement of joints

Movement is brought about by voluntary muscles which contract and relax. *Involuntary* muscle tissue is not joined to bones, but controls movements of stomach, intestines, diaphragm etc. Cardiac muscle controls movements of the heart.

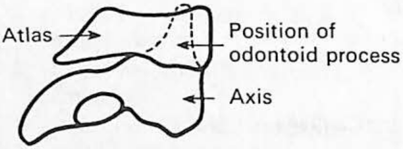
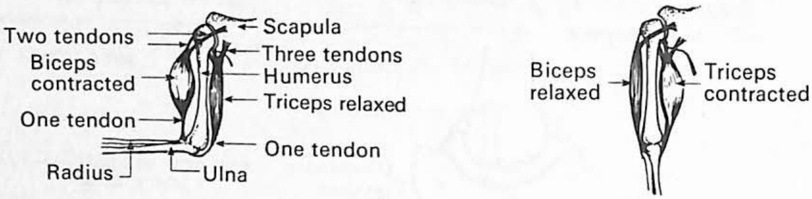


fig. 130 Atlas and axis

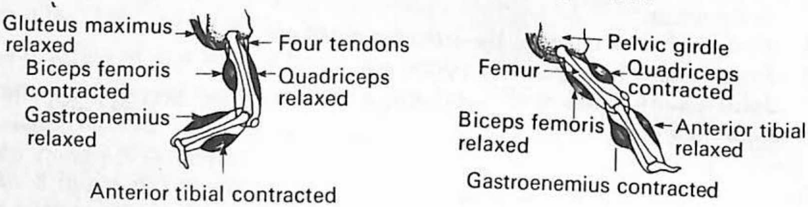

a Forearm raised

b Forearm lowered

fig. 131 Movement of a forearm

Voluntary muscles are joined to bones by tendons: non-elastic fibrous bands. One muscle of a pair contracts while the other relaxes to bring about movement of a joint.

Locomotion is brought about by the powerful muscles of the *leg* and lower part of the *trunk*.


a Knee and foot flexed

b Leg swung forward

c Leg straightened

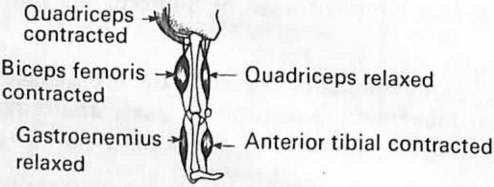


fig. 132 Movement of the leg in walking

11 Response

All living organisms show irritability, which is the ability to respond to a stimulus.

Response in plants

TACTIC RESPONSES OR TAXES

Result in *free swimming* movements towards (positive response), or away from (negative response), a stimulus such as light.
Unicellular green plants such as Euglena or Chlamydomonas swim towards light.

TROPIC RESPONSES OR TROPISMS

Result in *growth* movements. The direction of movement is determined by the direction of the stimulus.

Phototropism is the growth response to *light.* Shoots are positively phototropic.

Hydrotropism is the growth response to *water*. Roots are positively hydrotropic.

Geotropism is the growth response to *gravity*. Roots are positively geotropic, shoots are negatively geotropic.

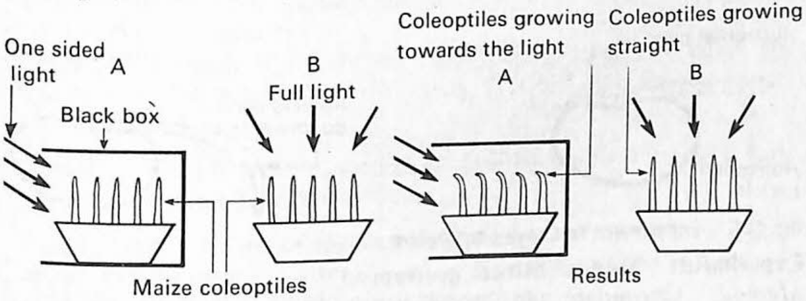

Coleoptiles growing towards the light
Coleoptiles growing straight
One sided light
A
B
Full light
Black box
A
B
Maize coleoptiles
Results

fig. 133 Experiment to show phototropism

Experiment: To demonstrate phototropism
Method: Germinate two pots of maize seedlings. When the coleoptiles are about 1″ long, place one pot in one-sided light and the other in full light as a control. Leave for two or three days.

Result: The seedlings exposed to one-sided light had grown towards the light. The control seedlings in full light had continued to grow straight.

Conclusion: Shoots of maize seedlings are positively phototropic.

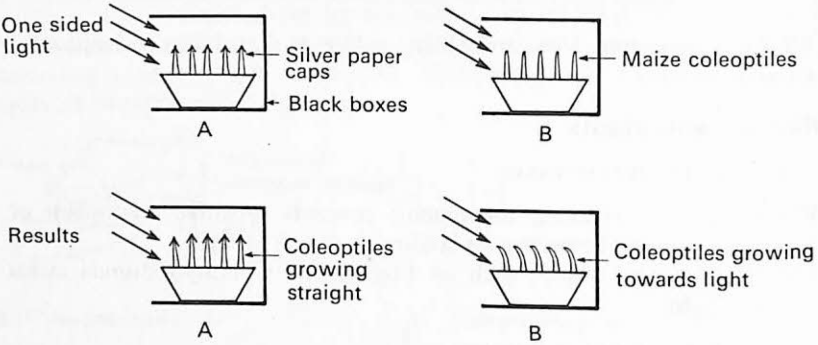


fig. 134 Experiment to find the perceptive region

Experiment: To find which region of the shoot perceives the stimulus of light

Method: Germinate two pots of maize seeds as before. Cover the tips of one set with silver paper caps, or, decapitate the top 2 mm. Place both pots in one-sided light and leave for two or three days.

Result: The seedlings with covered tips continued to grow straight, but the control seedlings grew towards the light.

Conclusion: The tips of maize seedlings perceive the stimulus of light.

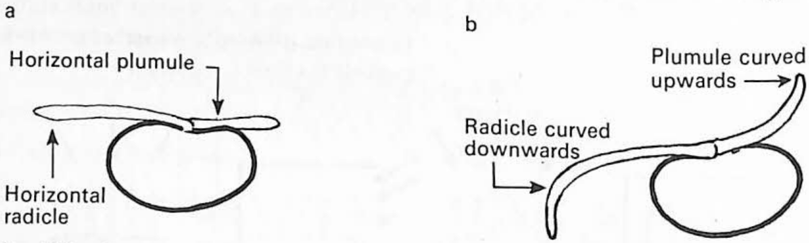


fig. 135 Experiment to show geotropism

Experiment: To demonstrate geotropism

Method: Germinate ten broad beans so that their radicles and plumules grow vertically. When the plumules are about $1\frac{1}{2}$ cm long, fix each bean onto moist blotting paper with the radicle and plumule horizontal. Leave for two or three days.

Result: The radicles curved downwards and the plumules curved upwards.

Conclusion: The radicles of broad beans are positively geotropic and the plumules are negatively geotropic.

Note: This experiment would be the same if performed in the dark. Plumules grow up through the soil by negative geotropism and only when they reach the light do they exhibit positive phototropism.

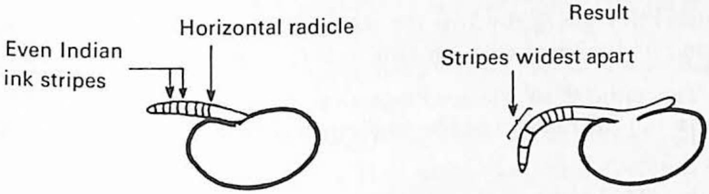


fig. 136 Experiment to find which region responds to gravity

Experiment: To find which region of the radicle responds to the stimulus of gravity

Method: Germinate ten broad beans with straight radicles about $2\frac{1}{2}$ cm long. Mark the radicles evenly with Indian ink stripes. Pin horizontally and leave for two or three days.

Result: The stripes just behind the tip were wider than the others.

Conclusion: The growing region just behind the tip responds to the stimulus of gravity.

Experiment: To find which region of the radicle perceives the stimulus of gravity

Method: Germinate ten broad beans with straight radicles about $2\frac{1}{2}$ cm long. Decapitate the end 2 mm. Pin horizontally and leave for two or three days.

Result: The radicles continued to grow horizontally but after a further three days curved downwards.

Conclusion: The tip of the radicle perceives the stimulus of gravity as there is no response after it is removed. The new tip is regenerated after about five days so response occurs then.

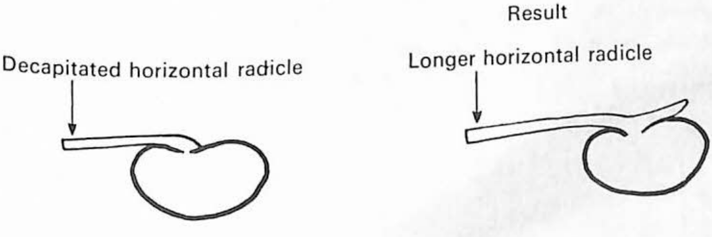


fig. 137 Experiment to find the perceptive region

Experiment: To demonstrate hydrotropism

Method: Germinate two sets of cress seeds in moist cotton wool on wire gauze, over two beakers of water. When the radicles are growing down through the gauze towards the water in the beakers, remove the water from one beaker. Leave for two or three days.

Result: The radicles of the seedlings over water continued to grow downwards, but the radicles of the seedlings over the dry beaker curved upwards.

Conclusion: The radicles of cress seedlings are positively hydrotropic as the ones over the dry beaker grew back to the only available source of water in the moist cotton wool. Hydrotropism is therefore stronger than geotropism.

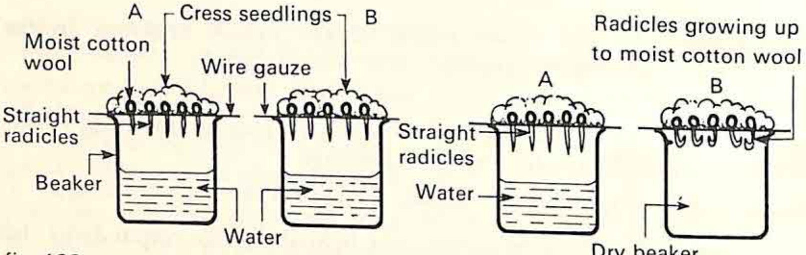


fig. 138 Experiment to show hydrotropism

Control of response in plants

Growth is controlled by plant *hormones* or *auxins* produced in the growing points of roots and shoots. Auxin accelerates the growth of shoots and retards the growth of roots.

Explanation of geotropic response

When the radicle and plumule are horizontal, auxin accumulates on the lower side. In the plumule it accelerates growth on the lower side resulting in upward curvature. In the radicle it retards growth on the lower side resulting in downward curvature.

Experiments with the plant hormone *indolyl acetic acid* have demonstrated the effects of the hormone. Maize coleoptiles are decapitated and their tips replaced with blocks of agar impregnated with indolyl acetic acid. When the blocks are placed asymmetrically, growth curvature results.

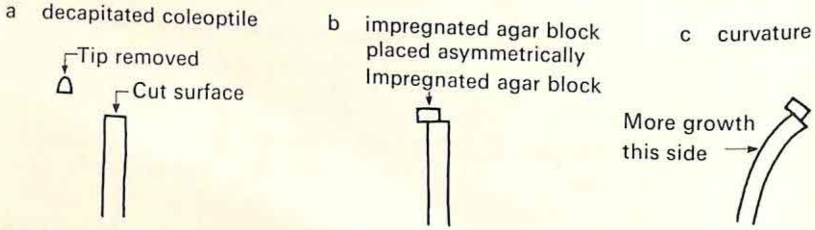


fig. 139 Effect of indolyl acetic acid

Response in animals

Amoeba No special sense organs. Responds to unfavourable stimuli such as touch with a fine needle, bright light, high temperature, chemicals etc., by withdrawing its pseudopodia. This is called "*rounding off*". If the unfavourable stimulus persists, the amoeba then moves away.

Earthworms and other invertebrates such as woodlice and blow-fly larvae show *tactic* responses. They react positively towards a humid atmosphere and negatively to bright light and contact.

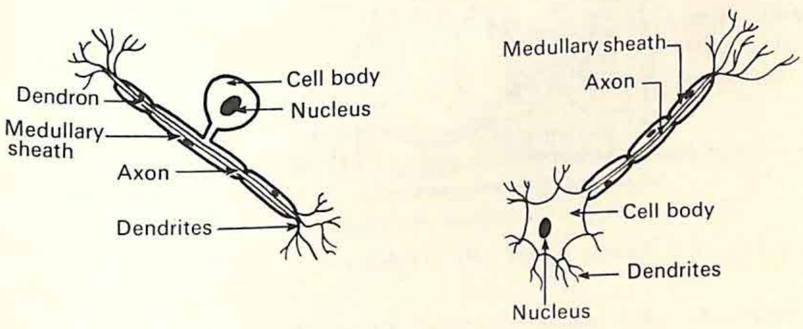
MAMMALS e.g. man

Nervous system of man

Composed of nerve cells or *neurones,* specialised for the conduction of impulses. The impulse passes from one neurone to another across a gap, the *synapse*. (fig. 140c)

Sensory neurones carry impulses from a receptor or sensory organ such as the eye to the central nervous system.

Motor neurones carry impulse from the central nervous system to a motor organ such as a muscle or gland.



a Sensory neurone

b Motor neurone

c Synapse between neurones

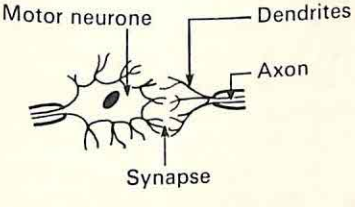


fig. 140 Neurones

Central nervous system
Consists of the *brain* and *spinal cord*, both made of many neurones. *Grey matter* is composed mainly of nerve-cell bodies and *white matter* consists of the nerve fibres.

Functions of the spinal cord

1 Conduction of impulses to and from the brain;
2 Reflex action.

Reflex action. *Involuntary* rapid response to a stimulus. Safety device. Brain is made aware of it afterwards. Examples:

a withdrawal of the hand from a hot object;
b the knee jerk.

The nerve path taken by the impulse in a reflex action is a *reflex arc*. It consists of:

i A *sensory organ* to receive the impulse e.g. skin;
ii A *sensory neurone* to relay the impulse to the spinal cord;
iii A *connector* or *internuncial neurone* to relay the impulse to:
iv A *motor neurone* to take the impulse to:
v A *motor organ* e.g. a muscle.

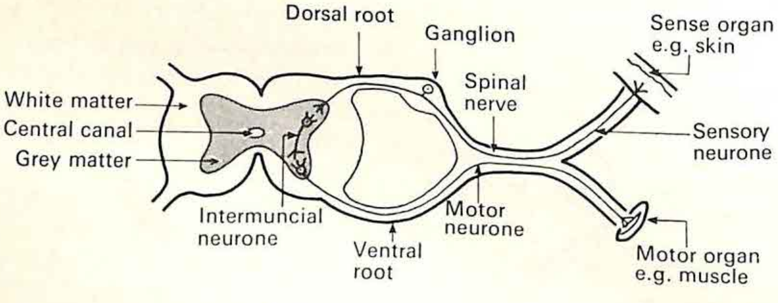


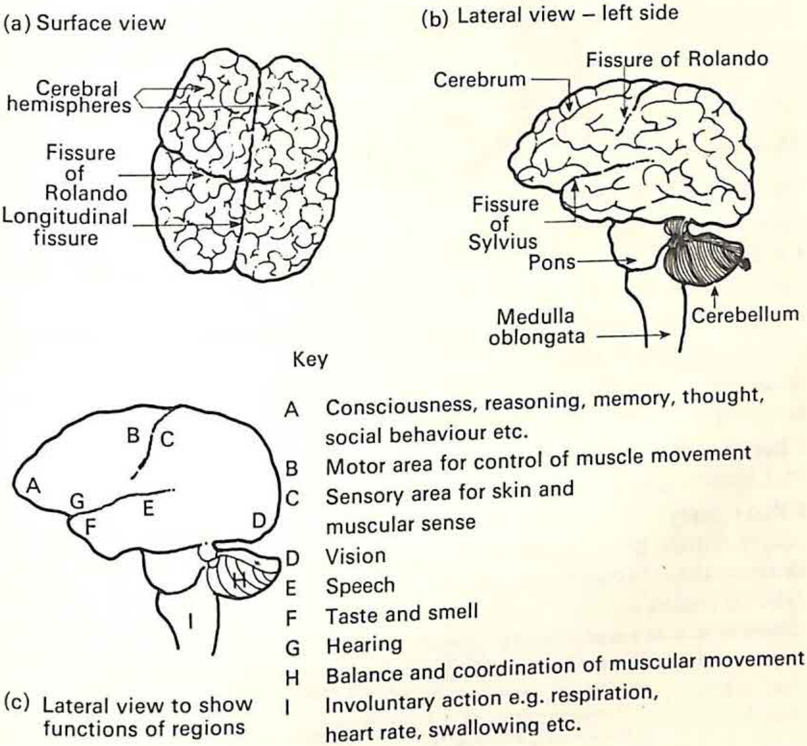
fig. 141 T. S. spinal cord and path of reflex arc

Note: A reflex action is never as simple as this, as groups of neurones and motor organs are usually involved.

Conditioned reflexes: Reflex action occurs in response to a stimulus other than the normal one which causes a response. Important in training and learning. Example: Pavlov's experiment. Pavlov rang a bell and noticed that it produced no response in his dogs. He then rang it for several days at the same time the dogs were fed. Later, he found that the sound of the bell made the dogs produce saliva, as they had replaced the normal stimulus of the sight, smell or taste of food with the ringing of the bell.

Functions of the brain

1. *Voluntary response* to impulses from sensory organs.
2. *Storage of information.* Memory and association centres for reasoning etc.
3. *Association centres* for co-ordination of body activities.
4. *Involuntary action* e.g. heart beat, breathing etc.


(a) Surface view

(b) Lateral view – left side

Key

A Consciousness, reasoning, memory, thought, social behaviour etc.
B Motor area for control of muscle movement
C Sensory area for skin and muscular sense
D Vision
E Speech
F Taste and smell
G Hearing
H Balance and coordination of muscular movement
I Involuntary action e.g. respiration, heart rate, swallowing etc.

(c) Lateral view to show functions of regions

fig. 142 Human brain

RECEPTOR ORGANS

These are adapted to perceive special stimuli and relay messages by *sensory nerve fibres* to the *central nervous system*. By their action, an animal is made aware of its environment. Mammals have five main types:

Organs	*Senses perceived*
Eyes	Sight
Ears	Hearing and balance
Tongue	Taste
Nose	Smell
Skin	Touch, temperature change, pain, etc.

The eye

Position Each eye is in an orbit in the skull, protected by the bone, eyebrows, eyelids, eyelashes and tears made in the lachrymal gland under the upper eyelid. It is moved in its socket by six muscles.

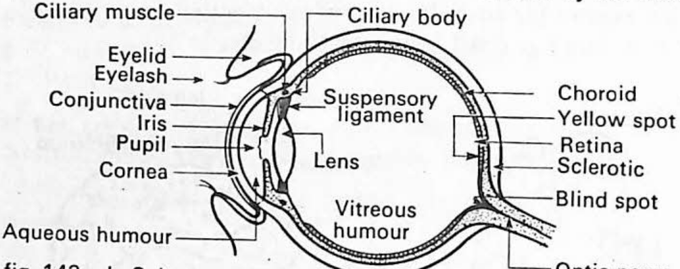


fig. 143 L. S. human eye

Structure and functions of parts of the eye

Conjunctiva: Mucous epithelial layer *protecting* front of eye and inside eyelids from dust, germs and dessication.

Cornea: Transparent coat at front of eye. Curved to start *refraction* of light passing through it.

Sclerotic: Opaque, white, non-elastic continuation of the cornea forming the outer coat. Tough for *protection.*

Choroid: Second layer containing *blood vessels* to *nourish* the eye, and *black pigment* to *reduce reflection.*

Ciliary body: Thickened edge of choroid in lens region, containing ciliary muscle fibres which control the *accommodation* of the lens, when near or distant objects are viewed.

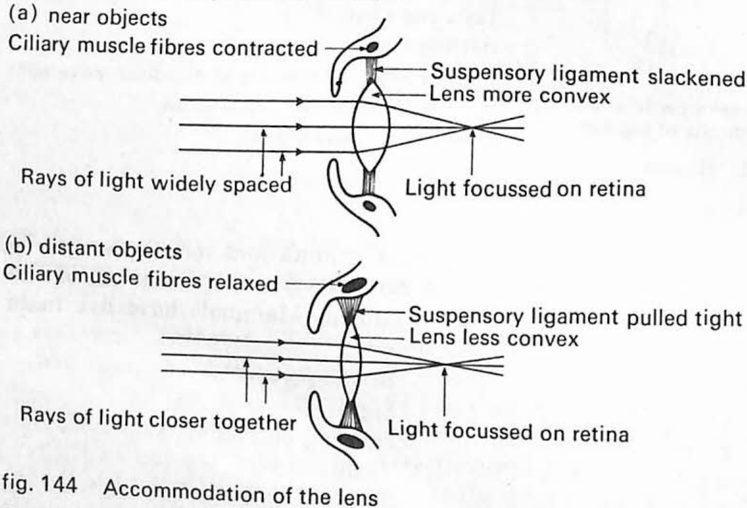

(a) near objects
Ciliary muscle fibres contracted
Suspensory ligament slackened
Lens more convex
Rays of light widely spaced
Light focussed on retina
(b) distant objects
Ciliary muscle fibres relaxed
Suspensory ligament pulled tight
Lens less convex
Rays of light closer together
Light focussed on retina

fig. 144 Accommodation of the lens

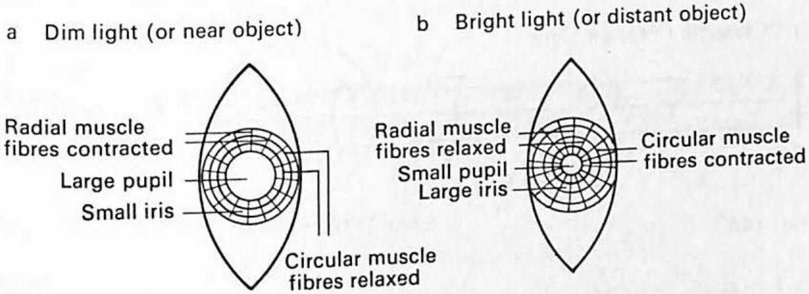
Suspensory ligament: Holds lens in place. Tension controlled by ciliary muscles (fig. 144).

Lens: Biconvex, transparent, crystalline body. Brings light rays to *focus on retina.*

Aqueous humour: Watery fluid in the anterior chamber in front of lens. Helps to *refract light,* keeps *shape of eye* and helps tension involved in accommodation.

Vitreous humour: Jelly-like fluid in posterior chamber behind lens. Similar functions to aqueous humour.

Iris: Disc-shaped continuation of choroid in front of lens. Contains colour pigment and sets of opposing radial and circular muscle fibres which increase or decrease the size of the circular hole, the pupil, in the centre, according to light intensity or nearness of object.


a Dim light (or near object)

b Bright light (or distant object)

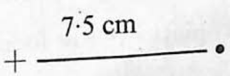
Radial muscle fibres contracted
Large pupil
Small iris
Circular muscle fibres relaxed
Radial muscle fibres relaxed
Small pupil
Large iris
Circular muscle fibres contracted

fig. 145 Action of iris

Retina: Inner, *light-sensitive* layer, composed of nerve cells called rods and cones. Rods are sensitive to light of low intensity and are important for seeing in dim light. Cones are sensitive to colour, and are of three types: red, green and blue. The image which falls on the retina is inverted and the nerve fibres carry the impulses down the optic nerve to the brain where it is interpreted in the correct position.

Yellow spot (fovea centralis): The most sensitive part of the retina directly opposite the lens.

Blind spot: The least sensitive part of the retina where the nerve fibres leave the eye to form the optic nerve. As no nerve cells are present, any image which falls on this spot cannot be seen.
The *spot and cross examination* illustrates the action of the blind spot.



Close your left eye. Look at the cross only with your right eye. Move the book slowly backwards and forwards. The spot disappears when light from it falls on the blind spot.

Common defects of vision

1 Short sight (myopia): Image focussed in front of retina.

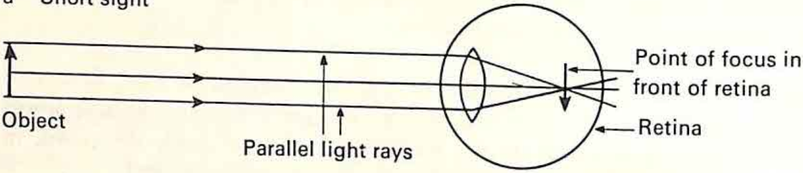
Causes: Either

a lens too convex, or

b eyeball too long.

Correction: Spectacles with concave lenses to widen the light rays.

a Short sight



b Correction of short sight

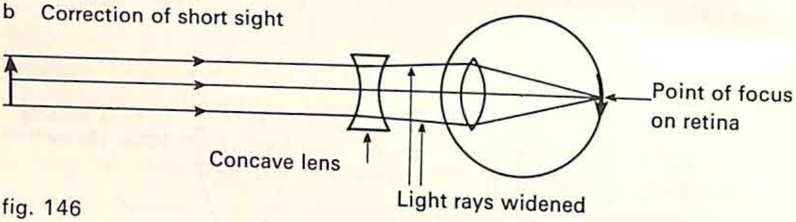
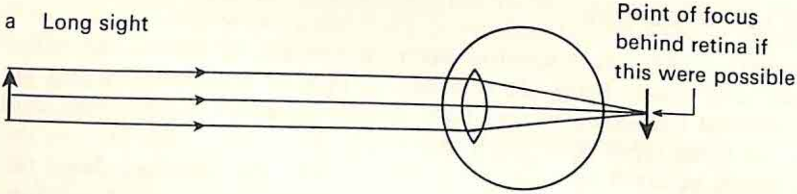


fig. 146

a Long sight



b Correction of long sight

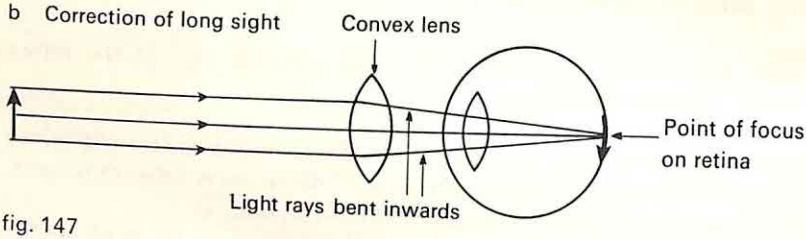


fig. 147

2 Long sight (hypermetropia): Image focussed behind retina.

Causes: Either

a lens not sufficiently convex due to weak ciliary muscles, or

b eyeball too short.

Correction: Spectacles with convex lenses to converge the light rays.

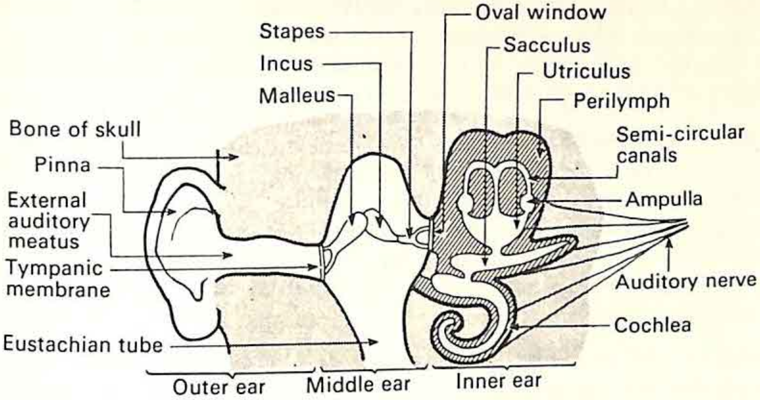


fig. 148 L. S. human ear

The ear

Position On either side of the head. *Outer ear* of projecting pinna and passage running through skull bone. *Middle ear* in air-filled cavity in skull. *Inner ear* in fluid-filled cavity in skull.

Structure and functions of the ear

Outer ear

Pinna or *lobe*: Stiffened with cartilage. Directs sound waves down the passage to the drum.

Ear passage (external auditory meatus): Concentrates sound waves on drum. Protective. Secretes wax to lubricate drum.

Ear drum (tympanic membrane): Circular stretched membrane. Vibrates when struck by sound waves.

Middle ear

Ossicles: Chain of three small bones, the hammer (malleus), anvil (incus), and stirrup (stapes). Transmit and amplify vibrations from drum to oval window.

Eustachian tube: Tube heading from middle ear to throat. Opens to equalise pressure on each side of the drum when atmospheric pressure changes.

Inner ear

Oval window: Membrane which transmits vibrations to the liquid or perilymph in the cochlea.

Cochlea: Coiled tube containing perilymph and endolymph separated by membranes. One membrane contains sensory nerve cells. Vibrations are transmitted through the liquids to the membranes, stimulating the sensory cells which pass impulses down the *auditory nerve* to the brain.

Semicircular canals: Canals arranged in three planes at *right angles* to each other. Contain endolymph. Each has a swelling or *ampulla* containing *sensory fibres* and chalky granules or *otoliths* embedded in *mucilage*. *Movement* of the head causes movement of the granules which pull on the fibres, which in turn send impulses to the brain. From these impulses the brain can control muscular movements necessary to control *balance*.

Utriculus and sacculus: Beneath the semi-circular canals. Contain endolymph and similar patches of *sensory fibres* which are also sensitive to changes in position.

Control of response in animals e.g. man
Co-ordination of body activities is brought about by the *nervous system* and the endocrine system which produces chemicals called *hormones*.

Hormones are chemical substances secreted by endocrine or *ductless* glands directly into the bloodstream. They circulate in the blood and have an effect when they reach a particular region or organ. Effects are normally much *slower* than those of nerves.

Pituitary gland: Situated at the base of brain. Two lobes. Size of a pea. Master gland producing several hormones which control the activities of the other ductless glands, and various others including the *growth hormone*.
Normal secretion of growth hormone produces normal growth.
Over-secretion in a child produces a giant.
Over-secretion in an adult produces a spade-like thickening of the bones of the hands, feet and jaw.
Under-secretion in a child produces a dwarf.

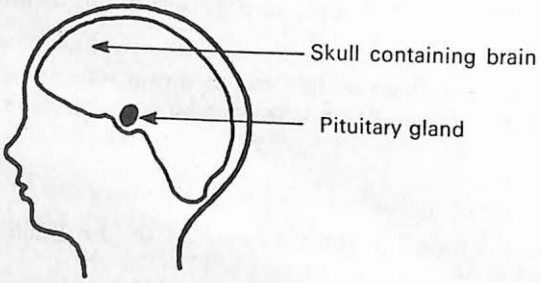


fig. 149 Position of pituitary gland

Thyroid gland: Situated in the neck. Two lobes. Produces the hormone thyroxine which controls the rate of body metabolism, growth and development.

Over-secretion produces an *increased* rate of metabolism e.g. rapid heart beat, nervousness, loss of weight etc. leading to goitre.
Under-secretion in a child produces a *cretin,* mentally and physically retarded.
Under-secretion in adults produces a sluggish metabolism e.g. slow heart beat, tiredness, increase in weight etc.

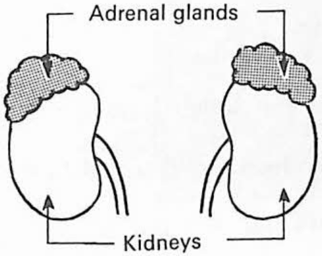


fig. 150 Position of adrenal glands

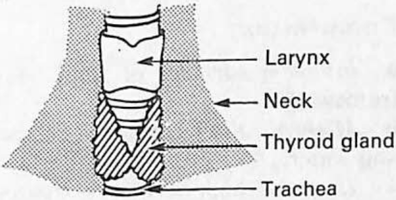


fig. 151 Position of thyroid gland

Adrenal glands Situated above the kidneys. Consist of cortex and medulla. Medulla secretes the hormone *adrenalin*. Hormone of 'fright, flight and fight'. Prepares the body for extra stress when in danger by the following major effects:-
a increasing the rate and strength of the heart beat;
b increasing the rate and depth of breathing;
c dilating blood vessels to the muscles and constricting those to the alimentary canal and skin;
d increasing blood sugar level, and oxidation of glucose to produce energy;
e widening eye-pupils, and retracting upper eyelid.

Reproductive organs
Testes and *ovaries* produce sex hormones which control:
a development of secondary sexual characteristics e.g. growth of body hair, change of body shape etc.;
b development of reproductive organs and production of sperm and ova;
c menstrual cycle in women;
d further development of womb after fertilization, and milk production in mammary glands.

12 Soil

Formation

Soil is formed by the breaking down or weathering of rock surfaces. Agents causing weathering are oxygen, wind, rain, temperature changes, plant roots, ice and surface water such as rivers, especially water containing dissolved carbon dioxide.

Sedementary soils occur in the area that the original weathering took place.

Transported soils have been moved from their original places e.g. alluvial soil.

Composition

a *Insoluble particles* of sand, clay, gravel etc. which form the soil framework.
b *Mineral salts* from the rocks or humus which are dissolved in the soil water.
c *Humus*, which is organic matter formed from decaying plants and animals.

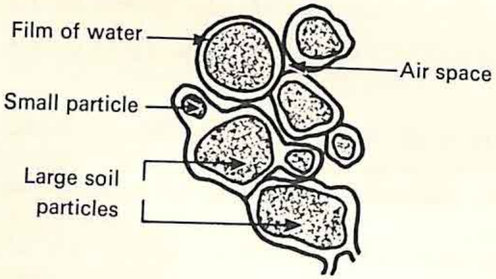


fig. 152 Soil structure

d *Water*, which forms a thin film around soil particles.
e *Air*, which occurs in spaces between the particles.
f *Living organisms* e.g. bacteria, fungi, earthworms, insects etc.

Physical and chemical properties

A soil which is the best medium for life has the following properties:
a *Capillarity*, as air spaces are not too large.
b *Drainage*, as air spaces are not too small.
c *Porosity*, as there is sufficient air for respiration.
d Sufficient *water retention*, but not enough to become waterlogged.
e Chemically neutral or alkaline *not* acidic.

Loams are the best all-round soils as they contain particles of varying sizes. Large particles create large air spaces for porosity and drainage, while the smaller particles create small air spaces for capillarity and water retention. A good *humus* content helps to hold water which prevents the mineral salts being washed out by rain. Humus provides nitrates and other mineral salts.

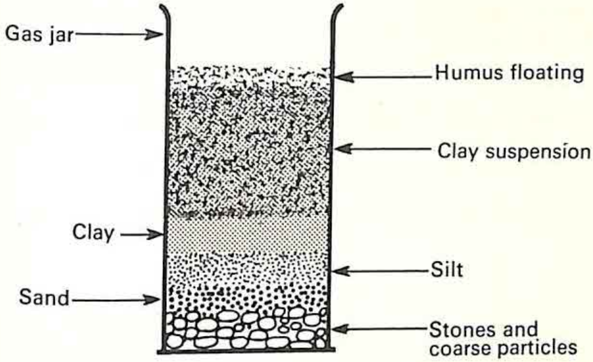


fig. 153 To find the solid composition of soil

Experiment: To find the solid composition of soil
Method: Shake a handful of soil with water in a 500 cm^3 gas jar. Leave to settle.

Result: Large particles settle first at the bottom, followed by smaller and smaller particles as shown in fig. 153. Humus floats on top.

Conclusion: The solid constituents of soil can be separated by shaking with water and allowing it to settle.

Experiment: To find the percentage of water in a soil sample
Method: Weigh an evaporating basin. Re-weigh it containing a sample of soil and subtract to obtain the weight of soil. Heat for 24 hours in a steam oven or over a water bath, to drive off soil water. Weigh again, then re-heat and continue the weighing, heating, process until constant weight is obtained.

Result:

Weight of soil = 50 gf

Weight of soil after heating to constant weight = 42 gf

Loss in weight = 8 gf

Percentage of water in soil sample $= \frac{8 \times 100}{50}$

$= 16\%$

Conclusion: Water makes up 16% of this soil sample.

Experiment: To find the percentage of humus in a soil sample

Method: Using dry soil from the previous experiment, heat strongly in a crucible or sand bath for about two hours to burn the humus. Weigh and re-heat until constant weight is obtained.

Result:

Weight of dry soil = 42 gf
Weight of soil after heating strongly to constant weight = 36 gf
Loss in weight = 6 gf

$$\text{Percentage of humus in soil sample} = \frac{6 \times 100}{42} = 14.28\%$$

Conclusion: Humus makes up 14.28% of this soil sample.

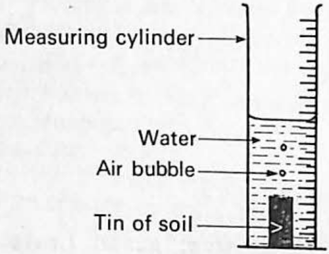


fig. 154 To find the percentage of air in soil

Experiment: To find the percentage of air in a soil sample

Method: Find the volume of a small round tin, punch holes in the bottom, and push it open-end first into the soil, keeping the soil as near as possible in its natural state. Dig it out, level off at the top and lower the tin full of soil into a large measuring cylinder containing a known volume of water. Read the new water level, then stir the soil with a stick to help release the air. Wait for about half an hour, stirring at intervals until no more air bubbles escape. Take the final reading.

Result:

Original volume of water = 300 cm^3
Volume of tin = 250 cm^3
Volume of water + tin + soil = 550 cm^3
Volume of soil = 250 cm^3
Final volume of water + tin + soil = 510 cm^3
Volume of air displaced = 40 cm^3

$$\text{Percentage of air in soil sample} = \frac{40 \times 100}{250} = 16\%$$

Conclusion: Air makes up 16% of this soil sample.

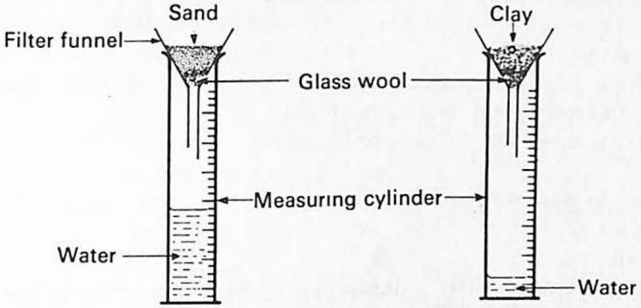


fig. 155 To compare water retention in sand and clay

Experiment: To compare the powers of water retention of sand and clay soil

Method: Lightly plug two filter funnels with glass wool. Half fill one with dry sand and half fill the other with an equal volume of dry clay. Stand them over measuring cylinders and simultaneously pour 100 cm^3 of water onto each. Measure the water which passes through in one hour.

Result: 84 cm^3 passed through sand in the first ten minutes and the remainder was retained. 2 cm^3 passed through clay in one hour.

Conclusion: Clay retains much more water than sand.

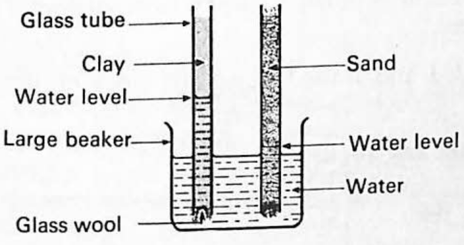


fig. 156 To compare capillarity in sand and clay

Experiment: To compare capillarity in sand and clay soils

Method: Plug the ends of two glass tubes 1 cm wide and at least 25 cm long, with glass wool. Fill one tube with dry sand and the other with dry clay. Stand them in a beaker of water and measure the distance travelled by the water at intervals of time.

Result: The water rose a few centimetres quickly in the sand, but had not risen much further after two days. The water rose slowly but steadily in the clay till it reached the top.

Conclusion: Clay has better capillarity than sand.

Summary of the physical properties of sandy soil

1. Large particles
2. Large air spaces
3. Good drainage, but little water retention
4. Quickly becomes wet, but dries out quickly
5. Poor powers of capillarity compared to clay

Summary of the physical properties of clay soil

1. Small particles
2. Small air spaces
3. Slow drainage. Good water retention, but becomes *waterlogged* easily as the soil swells and closes the air spaces.
4. Shrinks and cracks when dried, but it dries very slowly.
5. Good powers of capillarity but plant roots have difficulty overcoming the force to obtain the water.

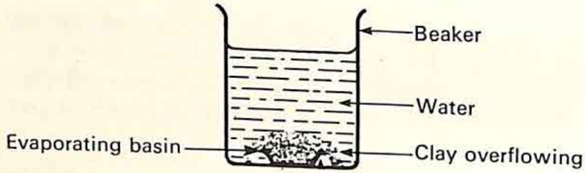


fig. 157 To show clay absorbs water and swells

Experiment: To show that clay absorbs water and swells

Method: Fill an evaporating basin with dry clay and lower it into a beaker of water. Leave for a day.

Result: The clay had expanded and flowed down the sides of the evaporating basin.

Conclusion: Clay absorbs water and swells.

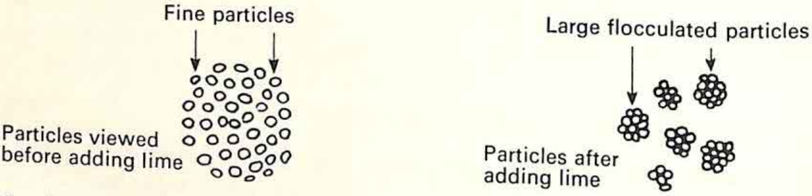

Fine particles
Particles viewed before adding lime
Large flocculated particles
Particles after adding lime

fig. 158 To find the effect of lime on clay

Experiment: To find the effect of lime on clay

Method: Shake small quantities of clay with water in two large gas jars. Add slaked lime to one gas jar. Observe the general effects, then remove small samples from each jar and observe under a low-powered microscope.

Result: The clay in the gas jar with lime began to flocculate into large particles and sink to the bottom. The clay without lime remained suspended in the water. Under the microscope large flocculated particles were seen in the first jar as shown in fig. 158.

Conclusion: Lime flocculates clay into larger particles.

Note: The addition of lime to clay soils increases particle size so improving drainage and porosity. Lime also neutralizes an acid soil and helps the action of the nitrogen-cycle bacteria.

Experiment: To find the effect of drying clay

Method: Spread wet clay evenly over the bottom of a large petri dish. Leave in a warm place to dry for a week.

Result: The clay had shrunk and dried as shown in fig. 159.

Conclusion: Clay shrinks and cracks when dried.

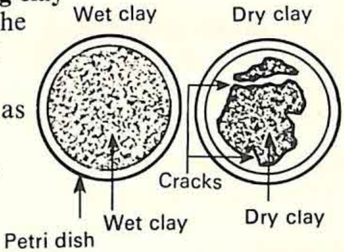


fig. 159 To find the effect of drying clay

Depletion of soil resources

Erosion by wind or rain moves or washes away exposed soil on sloping ground, so plants can no longer grow there.

Intensive cultivation of crops which use the soil resources without replacement of minerals also depletes the soil.

Soil conservation

This is a combination of methods used to combat soil erosion.

a Covering the soil

Soil is not left exposed during very rainy or windy seasons. A cover crop of potatoes or legumes etc. is planted. In rubber, coffee or tea plantations, some weeds are left between the trees so the soil is not exposed.

b Contour ploughing or ridging

Fields are ridged or ploughed across slopes, following the contour of the land, never up and down. Grass is often planted along the contours to grip the soil and prevent erosion.

c Monsoon drains or storm drains

These are often situated below high ground to prevent flooding of low-lying land or erosion of sloping land.

d Strip cropping

Fields are cultivated in strips following the land contours, with some strips bearing crops which cover the soil and others with crops that leave some soil exposed. In this way, erosion is reduced.

e Terracing

Terraces of soil, rocks or stones are built above each other along a contour, and soil is packed behind each one to give a terraced effect as shown in fig. 160. This reduces erosion.

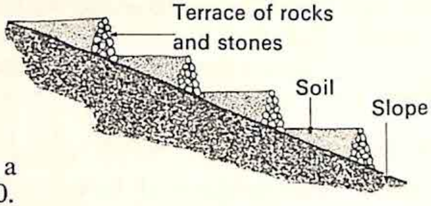


fig. 160 Terracing of a slope

MAINTENANCE OF SOIL FERTILITY

a Ploughing or digging

This breaks up heavy sticky soils, lets in water and air and brings fresh layers to the surface. It aids the work of the nitrogen cycle bacteria and buries weeds which decay and nourish the soil.

b Crop rotation

A different crop is grown each year in a three, four or five yearly rotation. Each succeeding crop makes different demands on the soil. Example of a four-year rotation:
1st year – wheat. Draws minerals from the deeper layers.
2nd year – potatoes or root vegetables e.g. beets which draw from the middle layers.
3rd year – oats which use much nitrate, and draw from the surface layers.
4th year – leguminous crop e.g. peas, beans, clover which increase the nitrogen content of the soil if the roots are ploughed in. Sometimes the whole crop is ploughed in; this is *green manuring*.
Rotation also discourages pests, as those that attack one crop do not find the same crop there the next year so they do not multiply.

c Extended bush-fallow system

Alternative to crop rotation but less efficient. Part of the jungle is cleared and burnt, then crops are planted for two years. It is then allowed to revert to jungle, a new area is cleared and the process is repeated. This allows the soil to revert to its natural state, to be used again in several years' time.

d Addition of manure or fertilizers

Used to replace minerals taken from the soil by the plants. Natural manure is slower to act than artificial fertilizers, but it helps the soil texture and water retention. Artificial fertilizers add mineral salts, mainly nitrates, phosphates, sulphates or ammonium salts. They do not affect the physical properties of soil. Examples: basic slag (calcium phosphate and lime), Chile saltpetre (potassium nitrate), ammonium sulphate, etc.

Ecology

This is the study of the *interrelationships* between animals and plants and their *environment*.

The *habitat* of an organism is the particular kind of environment in which it is found, depending on the effects of the climate, soil, presence of hills, seas, rivers etc., and the influence of other plants and animals.

Examples of habitats: seashore, grassland, pond, forest etc.

A *community* is a group of animals, plants, or both, living together in a particular habitat.

As plants and animals must be studied in their natural surroundings, and the students must investigate habitats themselves, this book will serve as a brief guide to the sort of work that should have been covered. Any one of the following ecological studies are acceptable, but there are many others quite as suitable.

1 Plants growing on waste ground

Five or six of the commonest plants present on a small area of waste ground should be studied and the following points noted in each case:

i Identification;
ii Accurate description;
iii Careful records of growth and development e.g. date of emergence of seedling, date of opening of first flower, length of time between flowering and fruit formation, mechanism of fruit or seed dispersal etc.;
iv Numbers of seedlings or vegetative shoots of each species and the numbers surviving to produce seeds should be recorded;
v Various experiments can be performed with seeds, e.g. seeds from one species can be collected and an attempt made to germinate a proportion of these at different times after gathering etc.

Accurate diagrams of the appearance of seedlings, vegetative plants, flowers, fruits and seeds should be made.

2 The invasion and colonization of a piece of cleared ground

An area of about 10 square metres or less should be chosen, and the predominant species should be identified and recorded. The area should then be cleared of all plants and the bare earth exposed. Daily observations should be made of the colonization that takes place. Each new species that appears should be identified and the time of its appearance should be recorded. The approximate area colonized by each type of plant should be estimated. The following observations, with drawings, should be made on each species:

i Time of appearance of first leaves;
ii Time of appearance of first flowers;
iii Time of appearance of first fruit;
iv Method of fruit or seed dispersal;
v Whether or not it dies after fruiting.

All animals such as birds, reptiles, insects etc. that visit the area should be recorded. It should be noted whether they favour any particular plant and to what extent the plants are affected by such animals.

3 Freshwater ponds

Man-made ponds, disused mining pools or fishing ponds etc., could be investigated using the same procedure outlined in **(1)** noticing adaptations of animals and plants to water. Observations and recordings should include details of temperature variations, acidity (pH), water movement, oxygen content of water and soil characteristics of bank and pond.

4 Special habitats

Places in which the plants and animals are fairly restricted e.g. seashore, mangrove swamp, etc. can be investigated in the same way, paying attention to influence of physical factors and adaptations of the species concerned.

Note: It is important that studies should not consist of a diary of uncollated observations. Students should realise the significance of the results such as the important environment factors that have led to adaptations and consequent survival of a species in a particular habitat.

The *flora* of a region refers to the *plants* present.
The *fauna* of a region refers to the *animals* present.

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